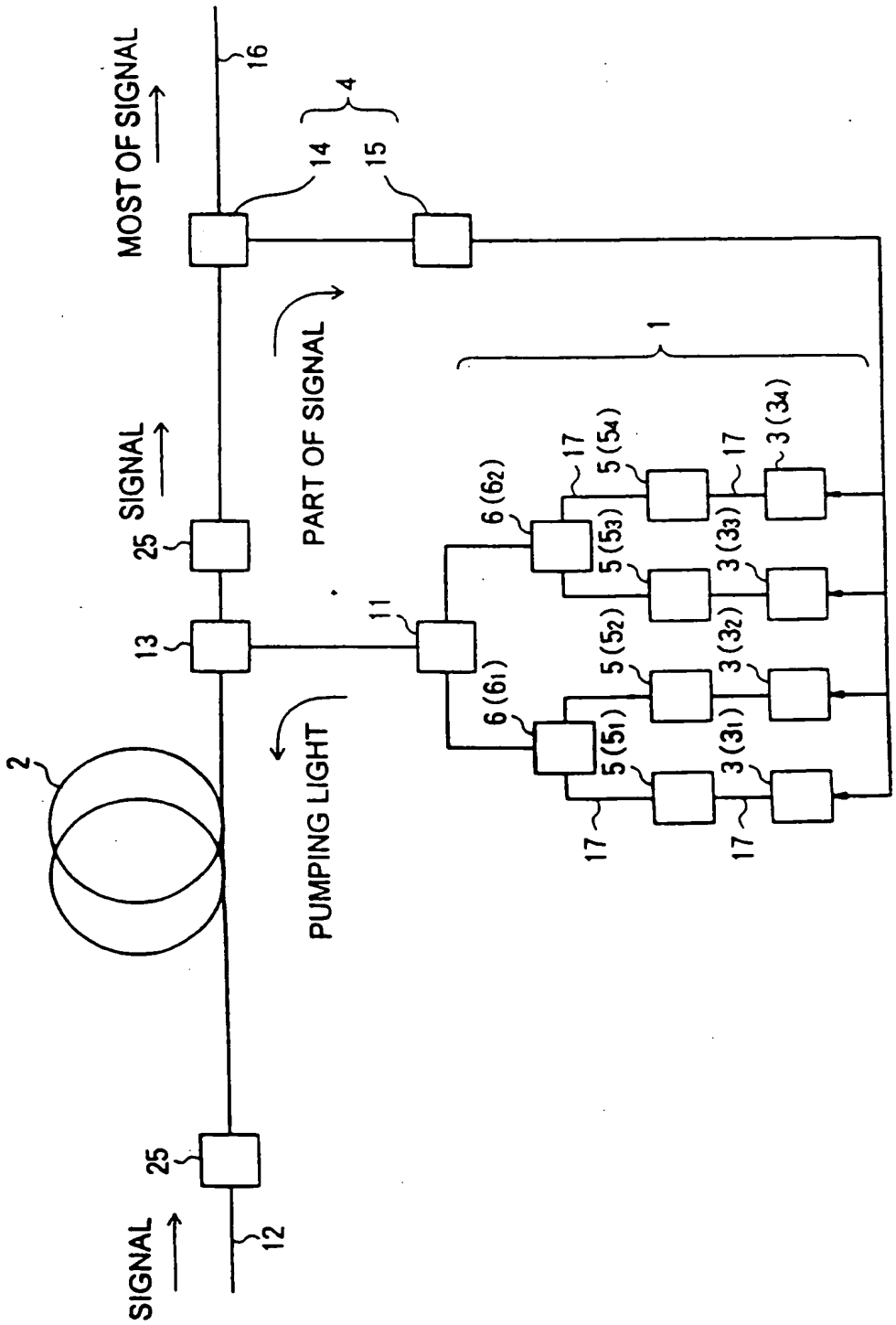

MOST OF SIGNAL
16
4
14
15
1
PART OF SIGNAL
SIGNAL
25
13
11
2
PUMPING LIGHT
6(62)
6(61)
5(54)
5(53)
5(52)
5(51)
3(34)
3(33)
3(32)
3(31)
17
25
SIGNAL
12

FIG. 1

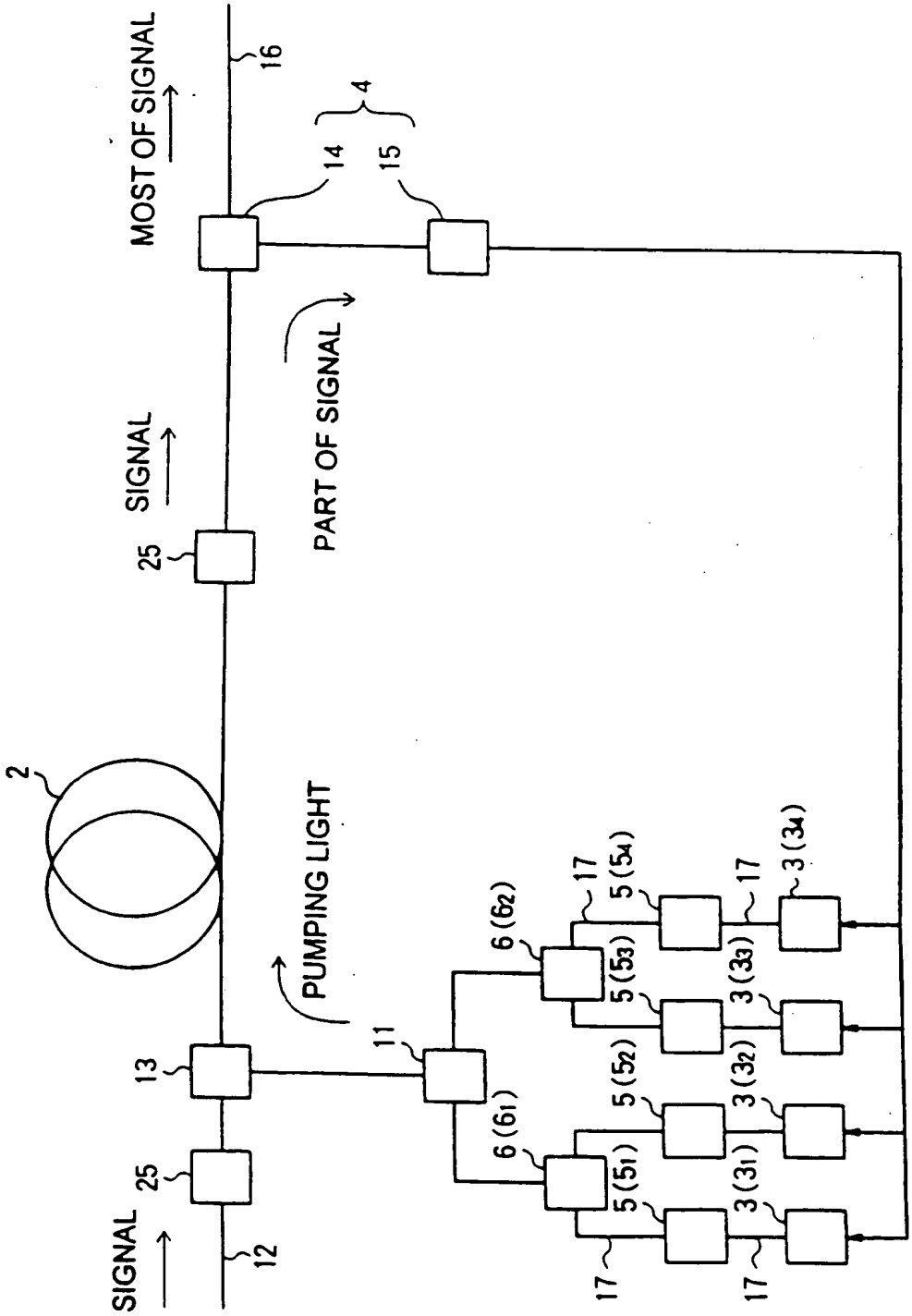

MOST OF SIGNAL
16
4
14
15
PART OF SIGNAL
SIGNAL
25
2
PUMPING LIGHT
11
13
25
SIGNAL
12
6(62)
6(61)
17
5(54)
5(53)
5(52)
5(51)
3(34)
3(33)
3(32)
3(31)

FIG. 2

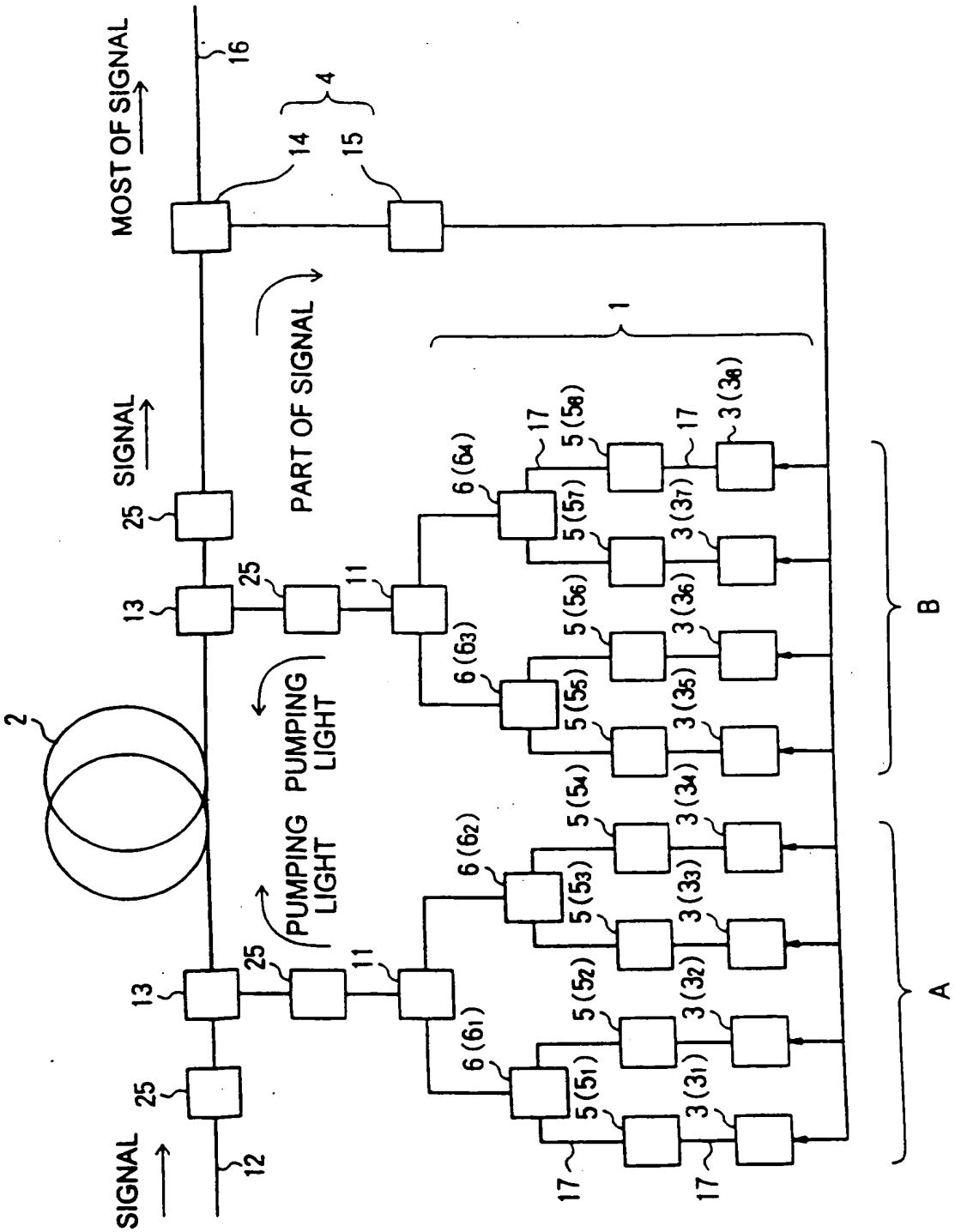

MOST OF SIGNAL
16
4
14
15
1
PART OF SIGNAL
SIGNAL
25
13
25
11
2
PUMPING LIGHT
PUMPING LIGHT
6(64)
6(63)
6(62)
6(61)
17
5(58)
5(57)
5(56)
5(55)
5(54)
5(53)
5(52)
5(51)
3(38)
3(37)
3(36)
3(35)
3(34)
3(33)
3(32)
3(31)
B
A
SIGNAL
12

FIG. 3

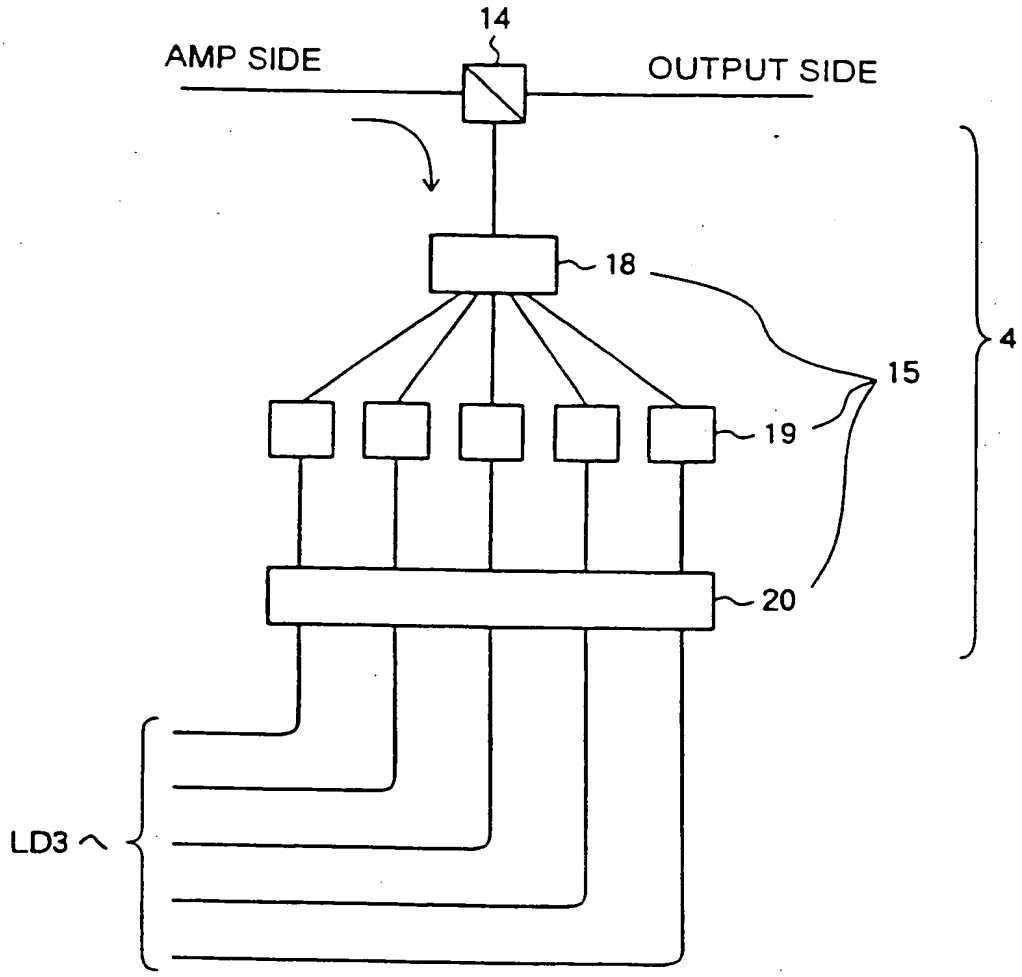


FIG. 4

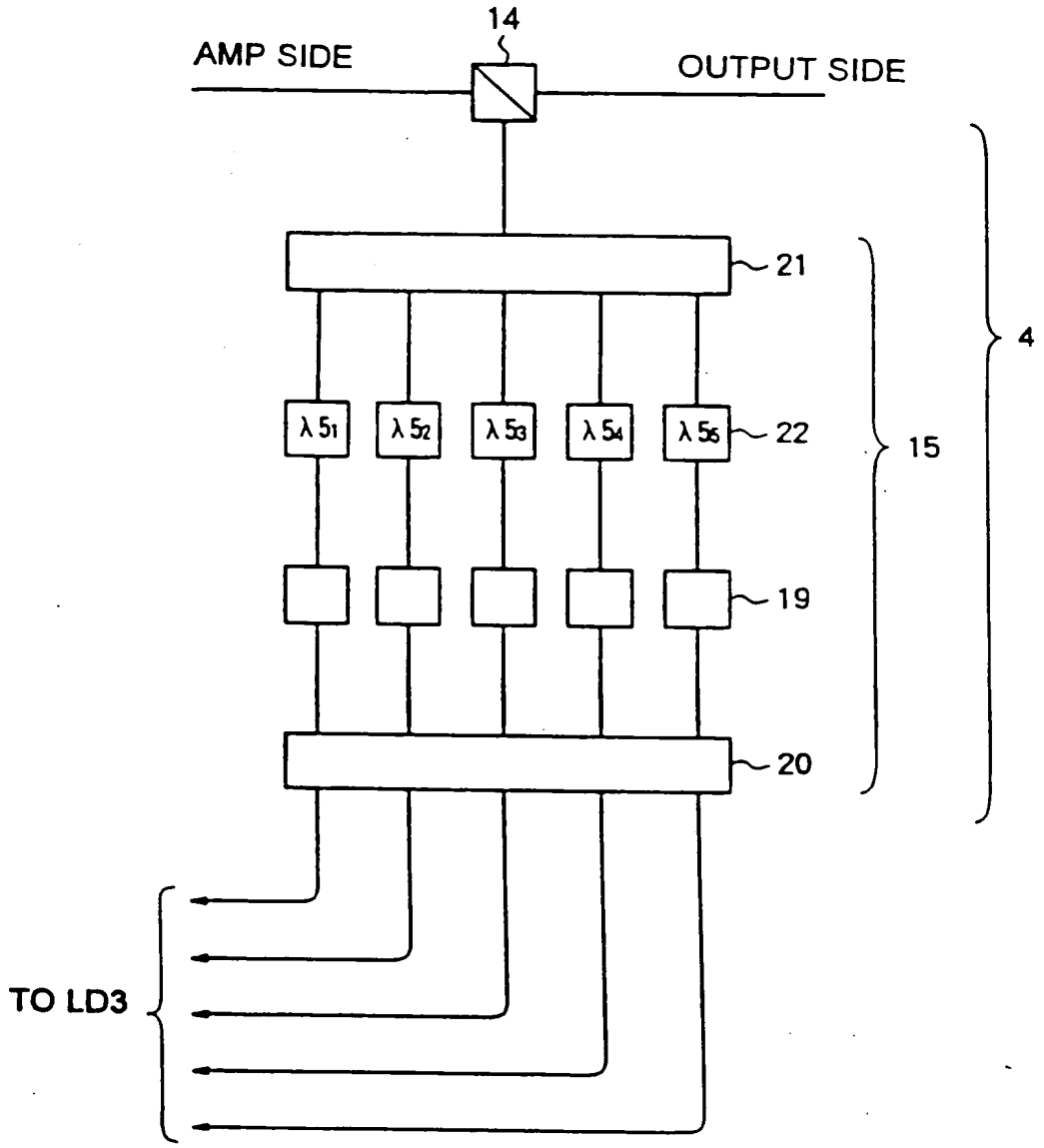

14
AMP SIDE
OUTPUT SIDE
21
λ51
λ52
λ53
λ54
λ55
22
15
4
19
20
TO LD3

FIG. 5

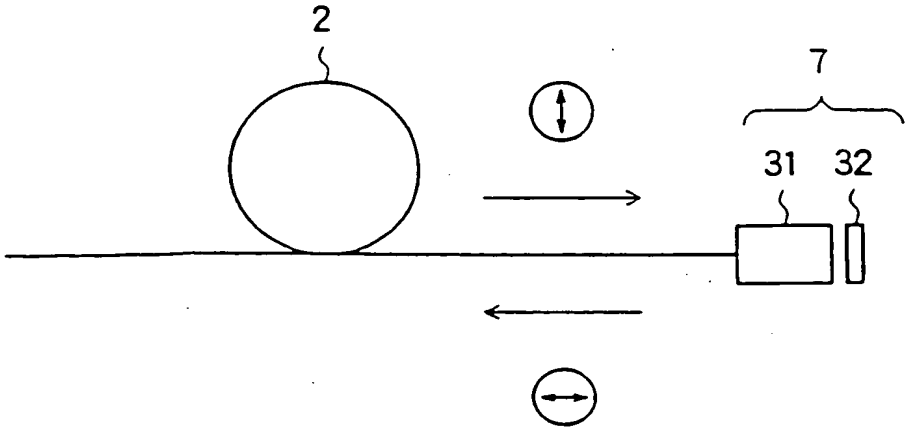


FIG. 6A

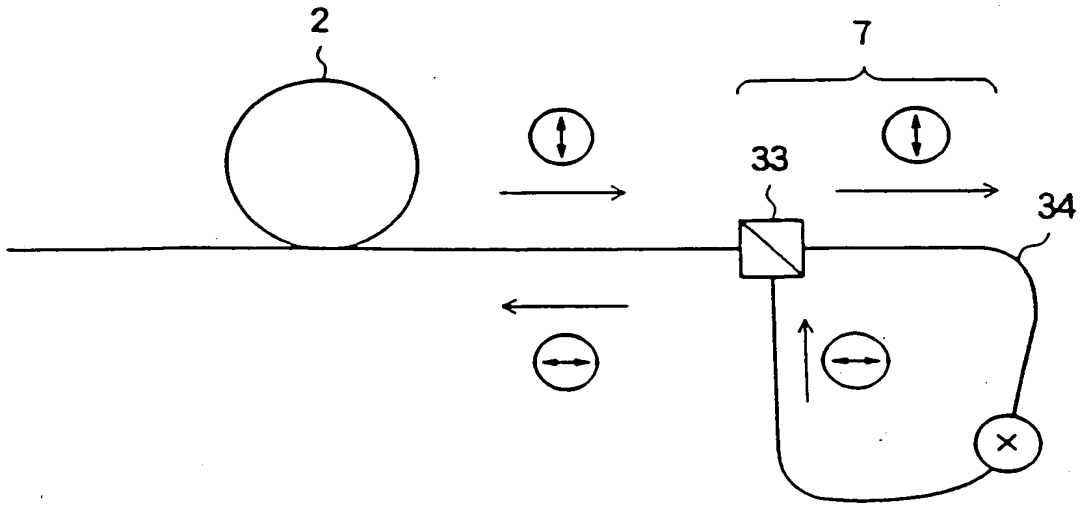


FIG. 6B

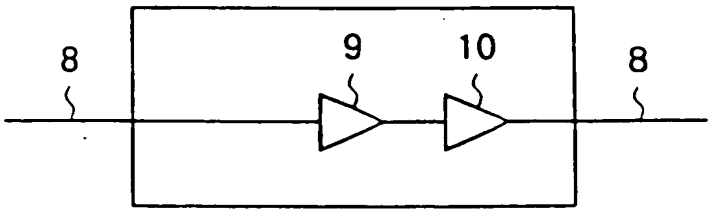


FIG. 7

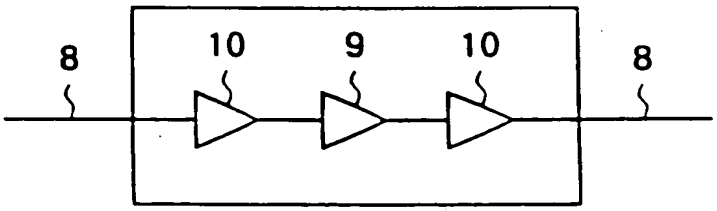


FIG. 8

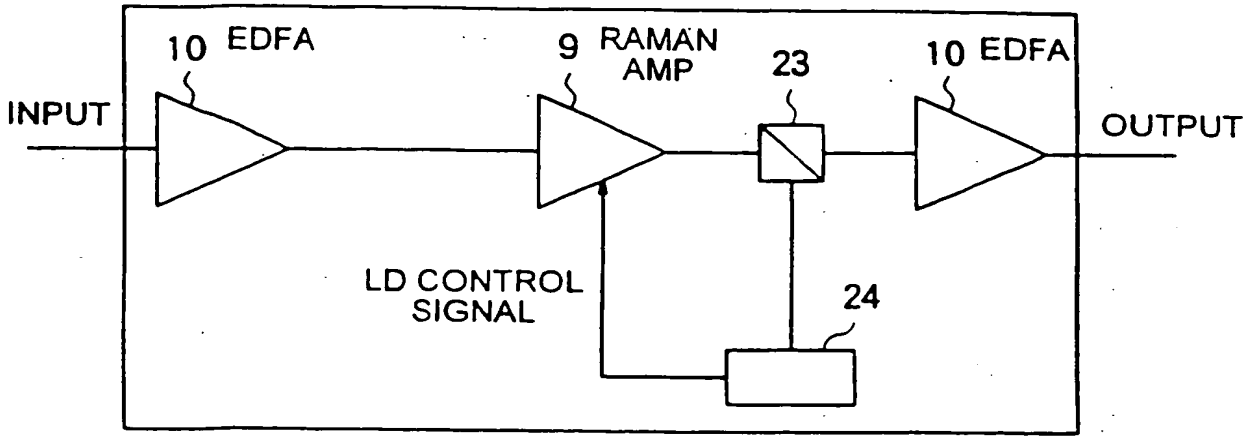

10 EDFA
9 RAMAN AMP
23
10 EDFA
INPUT
OUTPUT
LD CONTROL SIGNAL
24

FIG. 9

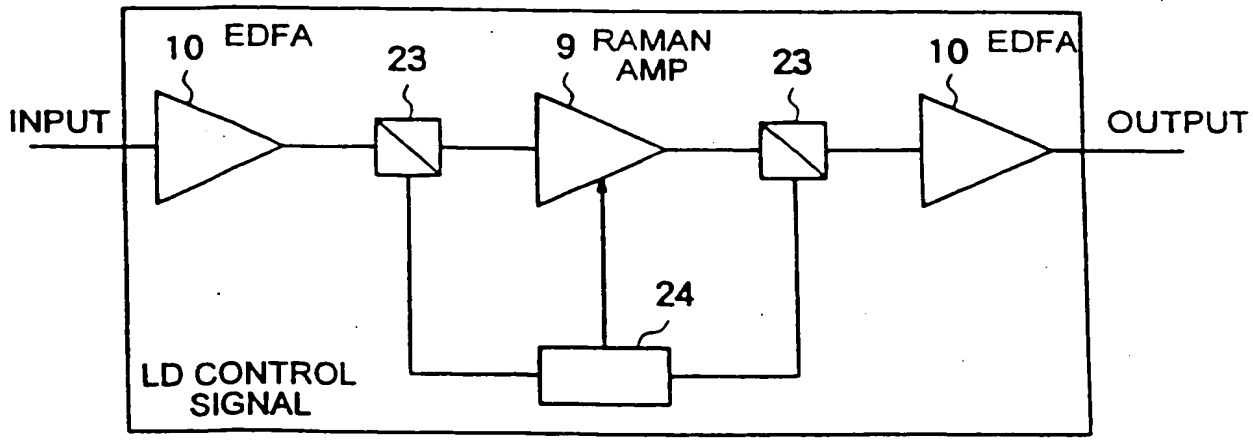

10 EDFA
23
9 RAMAN AMP
23
10 EDFA
INPUT
OUTPUT
24
LD CONTROL SIGNAL

FIG. 10

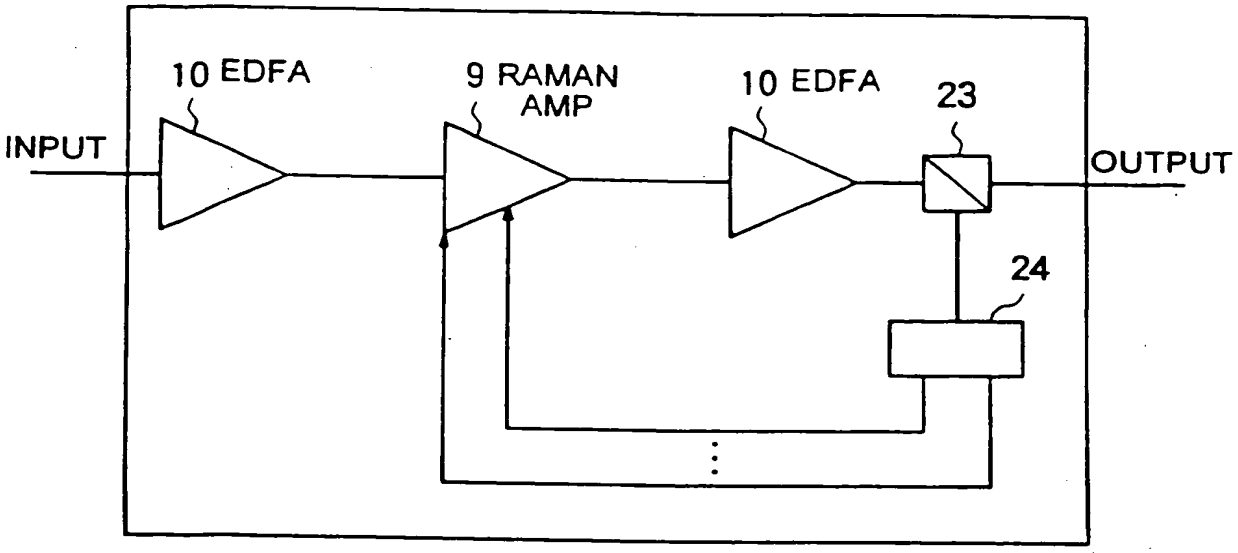


FIG. 11

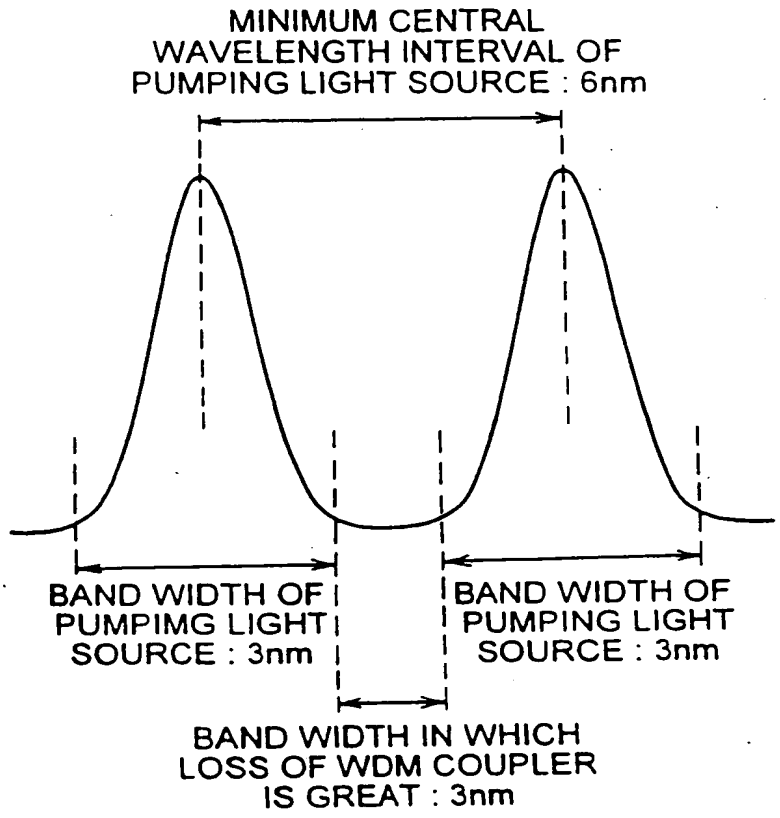

MINIMUM CENTRAL WAVELENGTH INTERVAL OF PUMPING LIGHT SOURCE : 6nm
BAND WIDTH OF PUMPIMG LIGHT SOURCE : 3nm
BAND WIDTH OF PUMPING LIGHT SOURCE : 3nm
BAND WIDTH IN WHICH LOSS OF WDM COUPLER IS GREAT : 3nm

FIG. 12

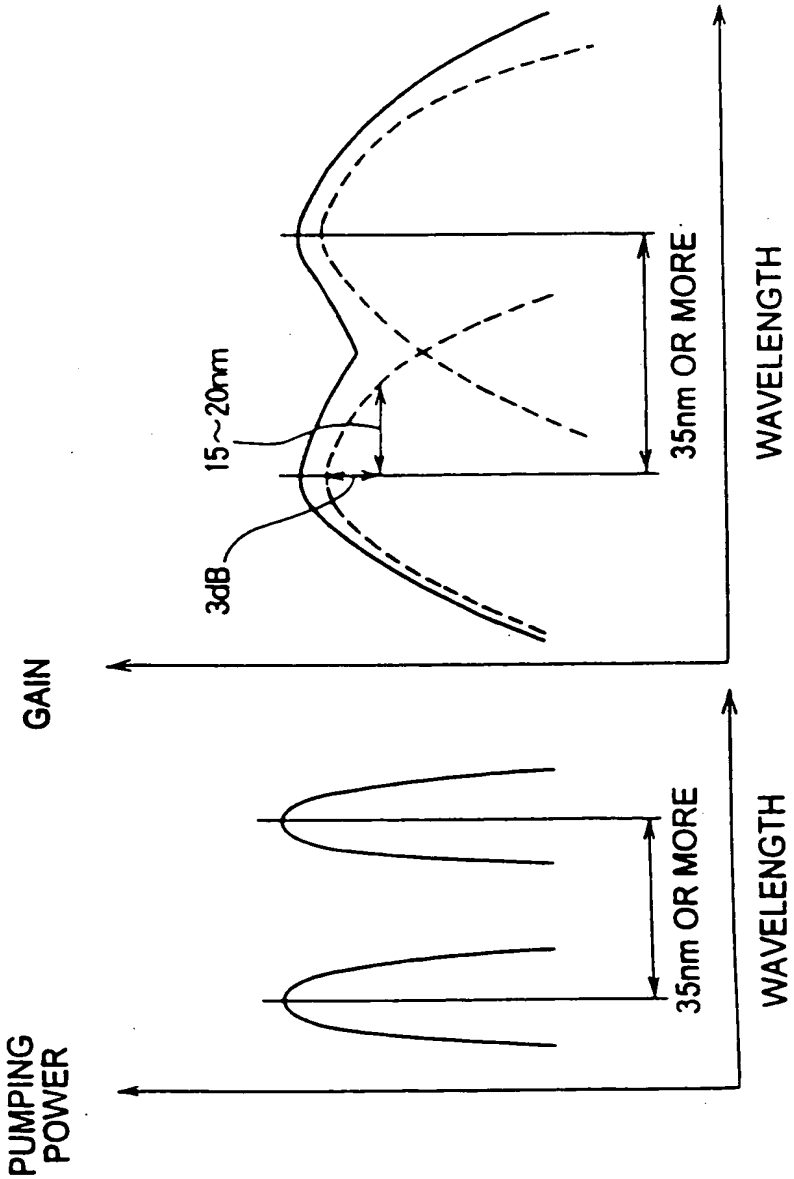
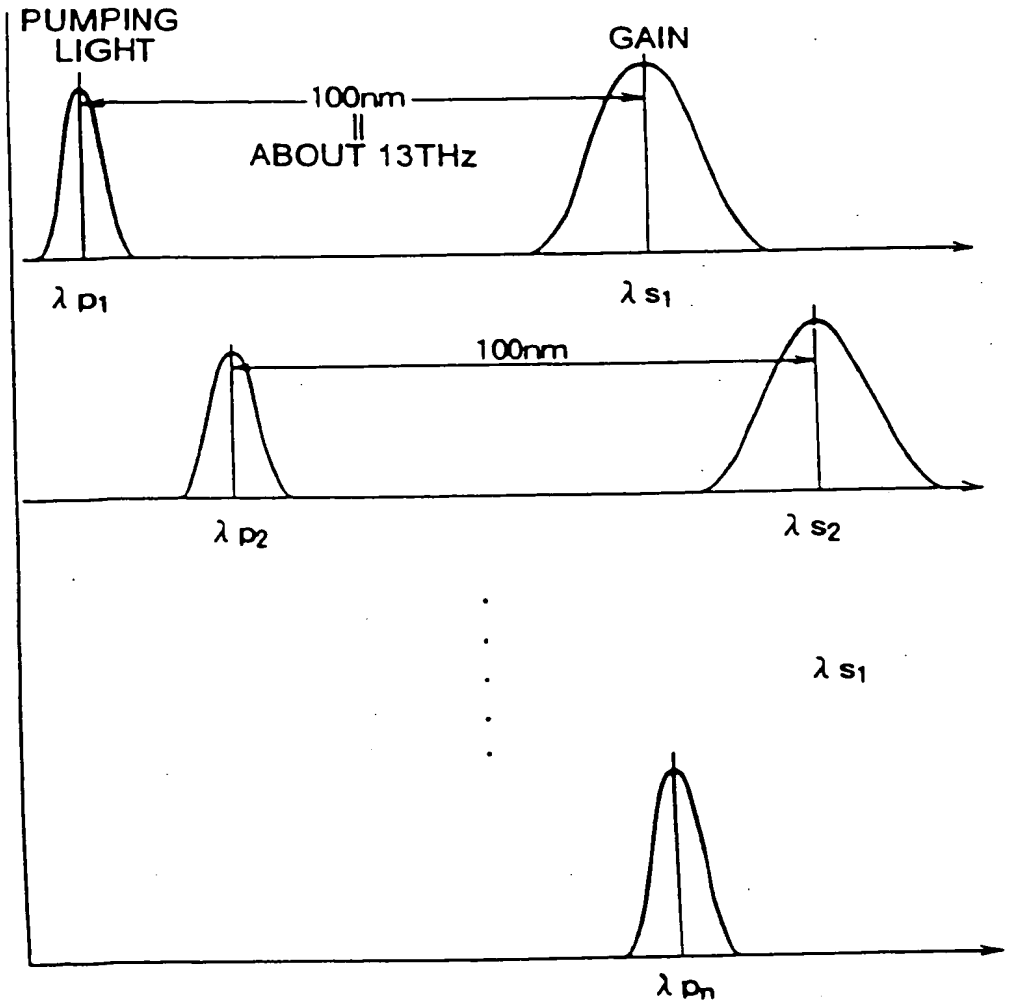


FIG. 13B

FIG. 13A



IN ORDER NOT TO OVERLAP $\lambda p_n < \lambda s_1$

$\Downarrow$

$\lambda p_n - \lambda p_1 < 100nm$

FIG. 14

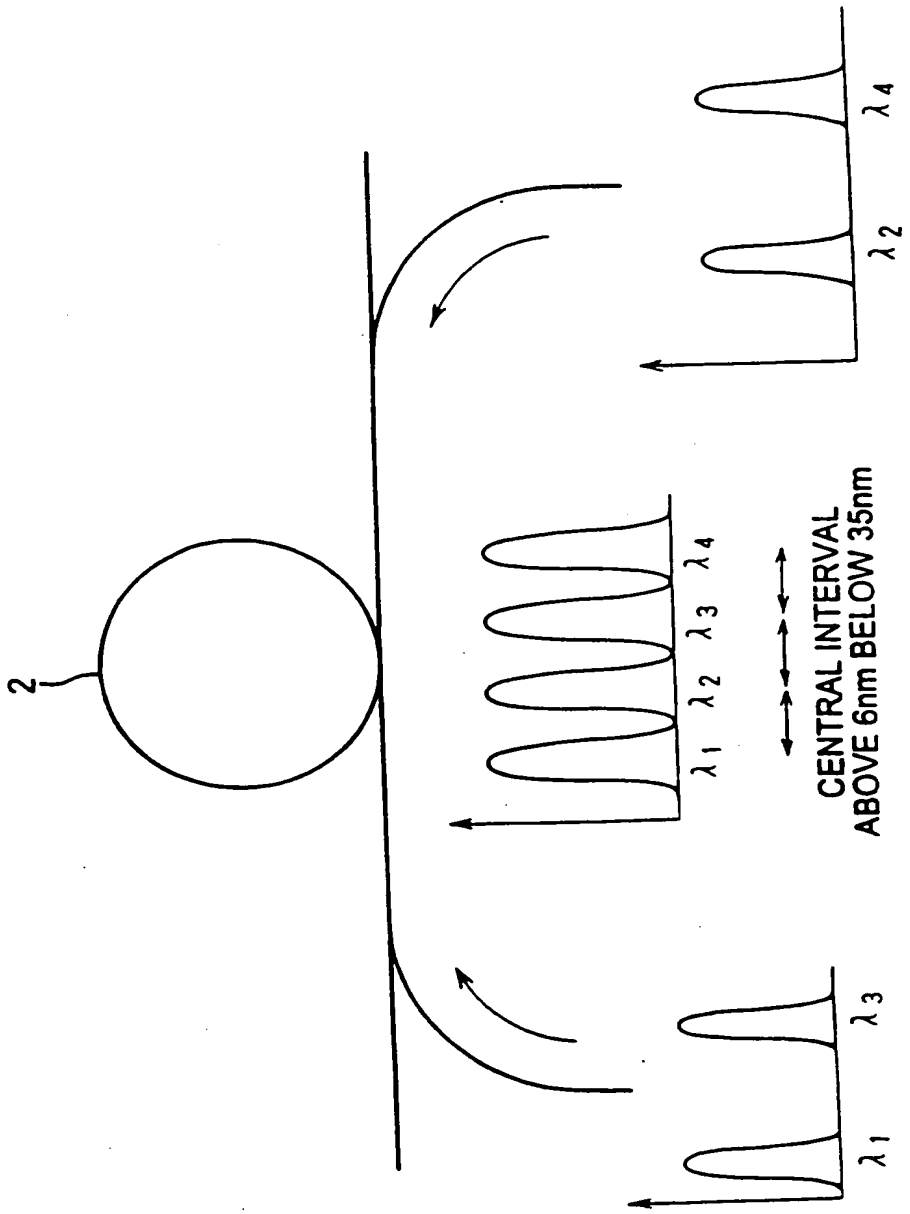
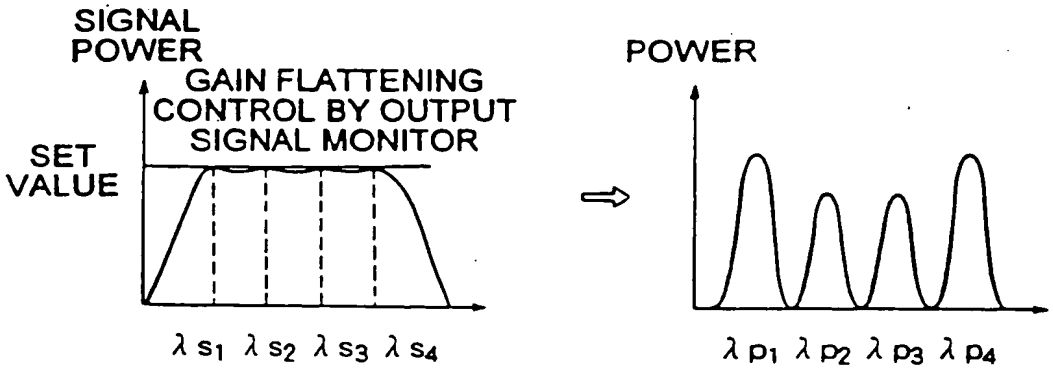


FIG. 15



$$\lambda s_1 \fallingdotseq \lambda p_1 + 100nm$$
$$\lambda s_2 \fallingdotseq \lambda p_2 + 100nm$$
$$\lambda s_3 \fallingdotseq \lambda p_3 + 100nm$$
$$\lambda s_4 \fallingdotseq \lambda p_4 + 100nm$$

FIG. 16

REPEATER SPECIFICATION		①	②	③
REPEATER INPUT P_{in}	[dBm/ch]	-20 ± 3	-15 ± 2	-15 ± 1
REPEATER OUTPUT P_{out}	[dBm/ch]	10	10	5
DCF LOSS L_d	[dB]	10 ± 2	8 ± 1.5	6 ± 1

FIG. 17A

EDFA DESIGN EXAMPLE			①	②	③
AMPLIFIER 1 GAIN	G_1	[dB]	20 ± 3	15 ± 2	15 ± 1
AMPLIFIER 2 GAIN	G_2	[dB]	20 ± 2	18 ± 1.5	11 ± 1
REPEATER GAIN	G_r	[dB]	30 ± 3	25 ± 2	20 ± 1

FIG. 17B

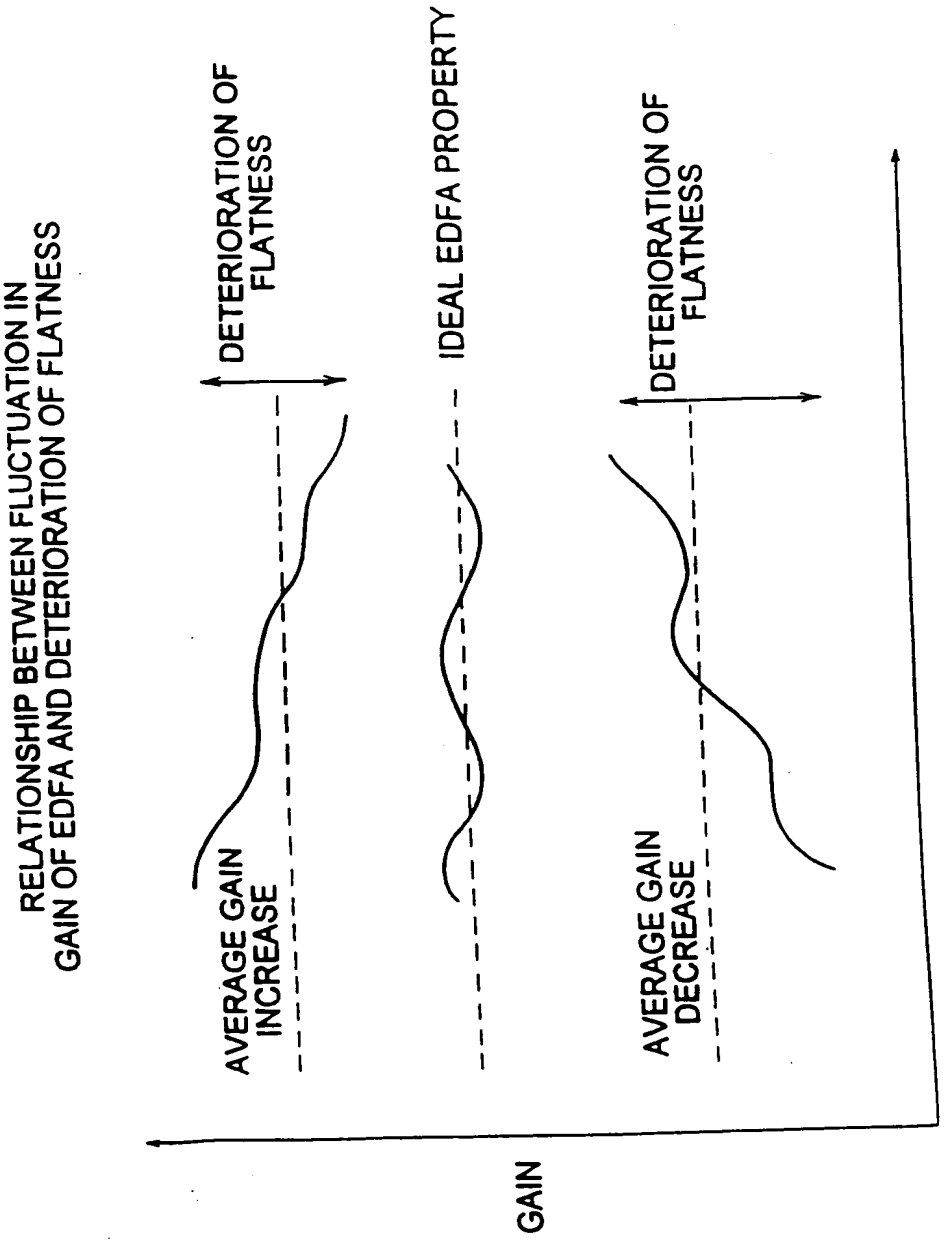

RELATIONSHIP BETWEEN FLUCTUATION IN GAIN OF EDFA AND DETERIORATION OF FLATNESS
DETERIORATION OF FLATNESS
IDEAL EDFA PROPERTY
DETERIORATION OF FLATNESS
AVERAGE GAIN INCREASE
AVERAGE GAIN DECREASE
GAIN
WAVELENGTH

FIG. 18

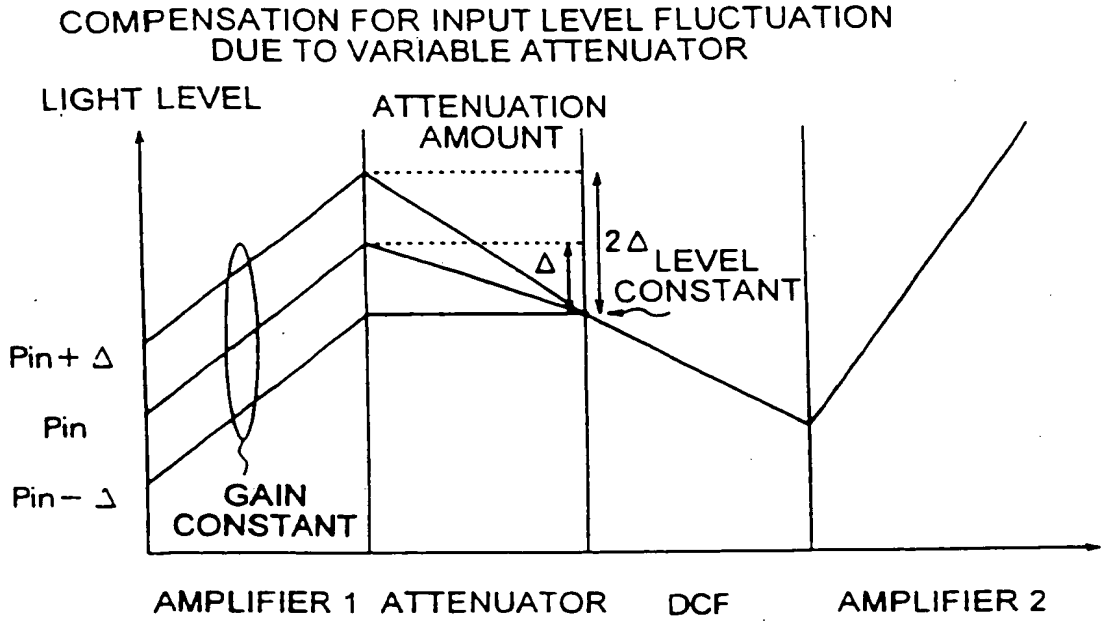


FIG. 19A

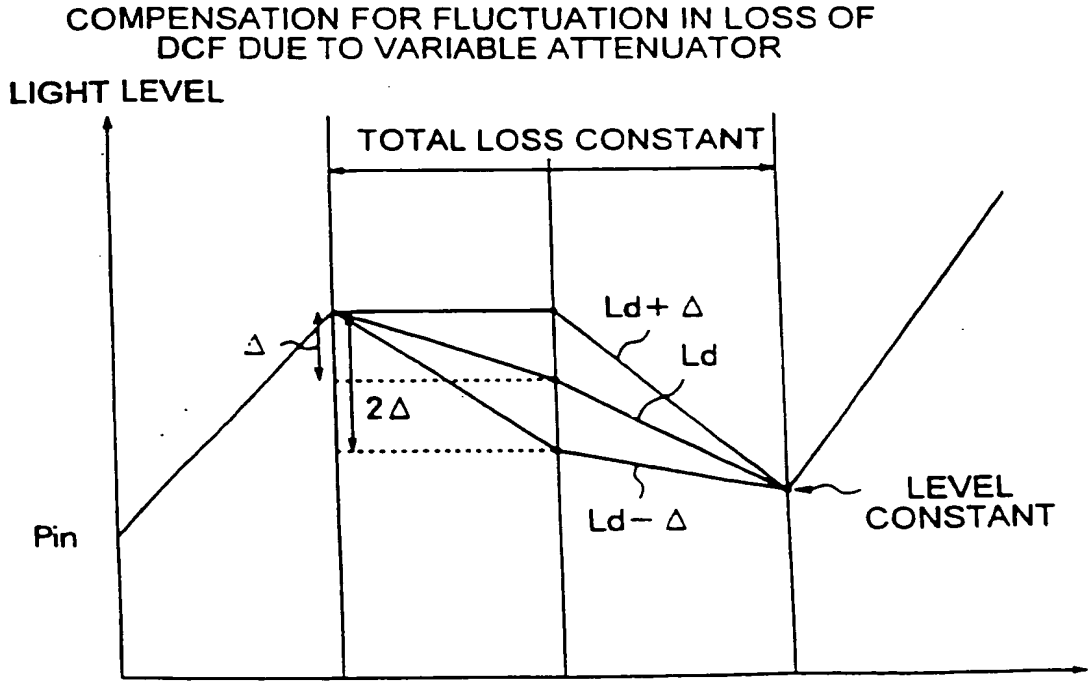


FIG. 19B

SPECIFICATION	①	②	③
REPEATER INPUT	−20±3	−15±2	−15±1
REPEATER OUTPUT	+10	+10	+5
DCF LOSS	10±2	8±1.5	6.5±1

FIG. 20A

AMPLIFIER 1	13	13	13
AMPLIFIER 2	10	10	10
RAMAN GAIN	17±5	10±3.5	3±2
REPEATER GAIN	30±3	25±2	20±1

FIG. 20B

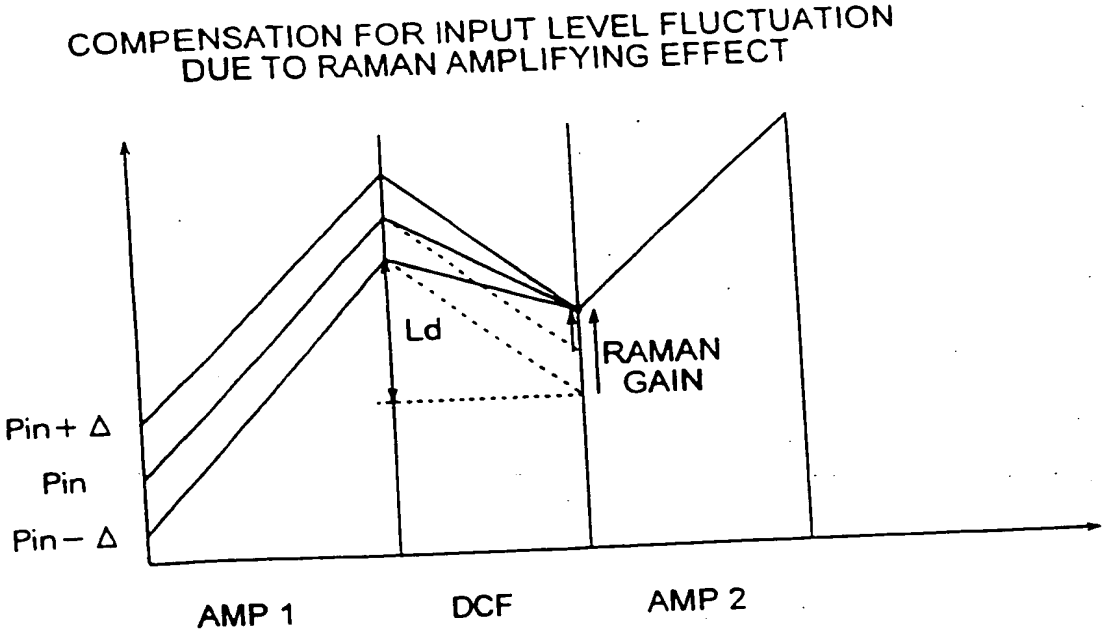


FIG. 21A

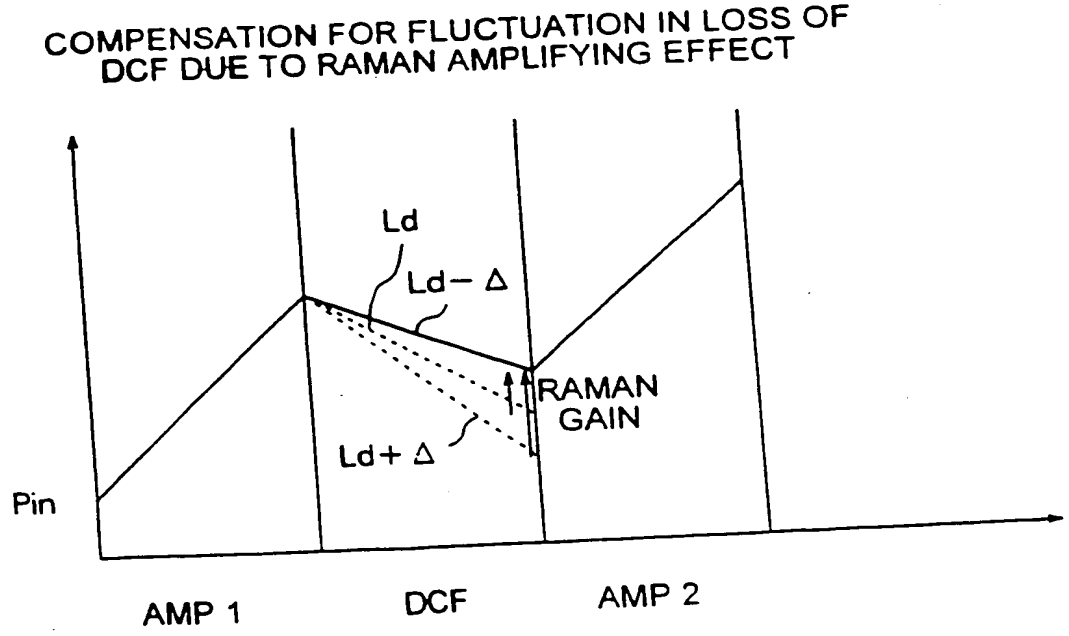


FIG. 21B

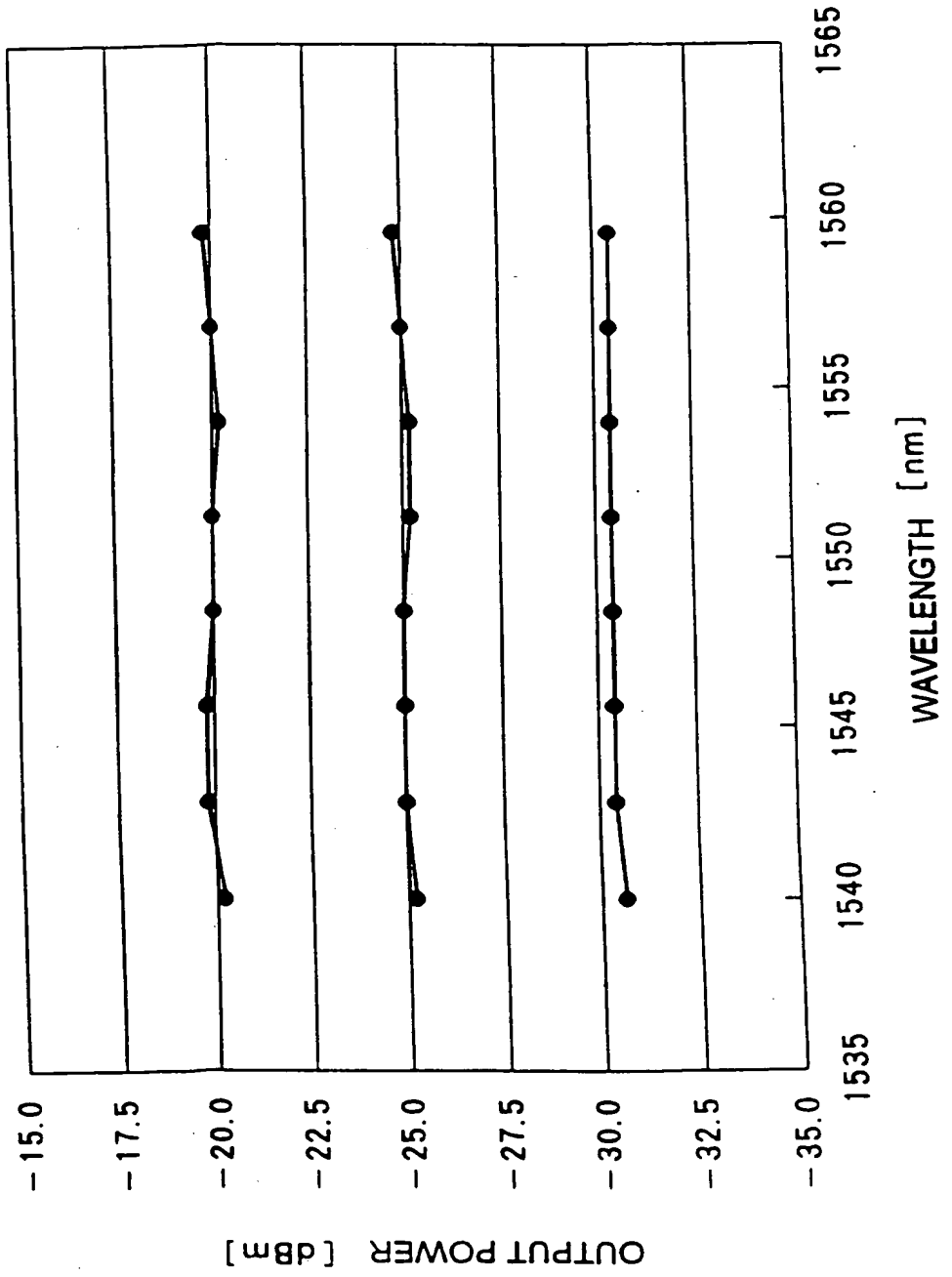

OUTPUT POWER [dBm]
-15.0
-17.5
-20.0
-22.5
-25.0
-27.5
-30.0
-32.5
-35.0
1535
1540
1545
1550
1555
1560
1565
WAVELENGTH [nm]

FIG. 22

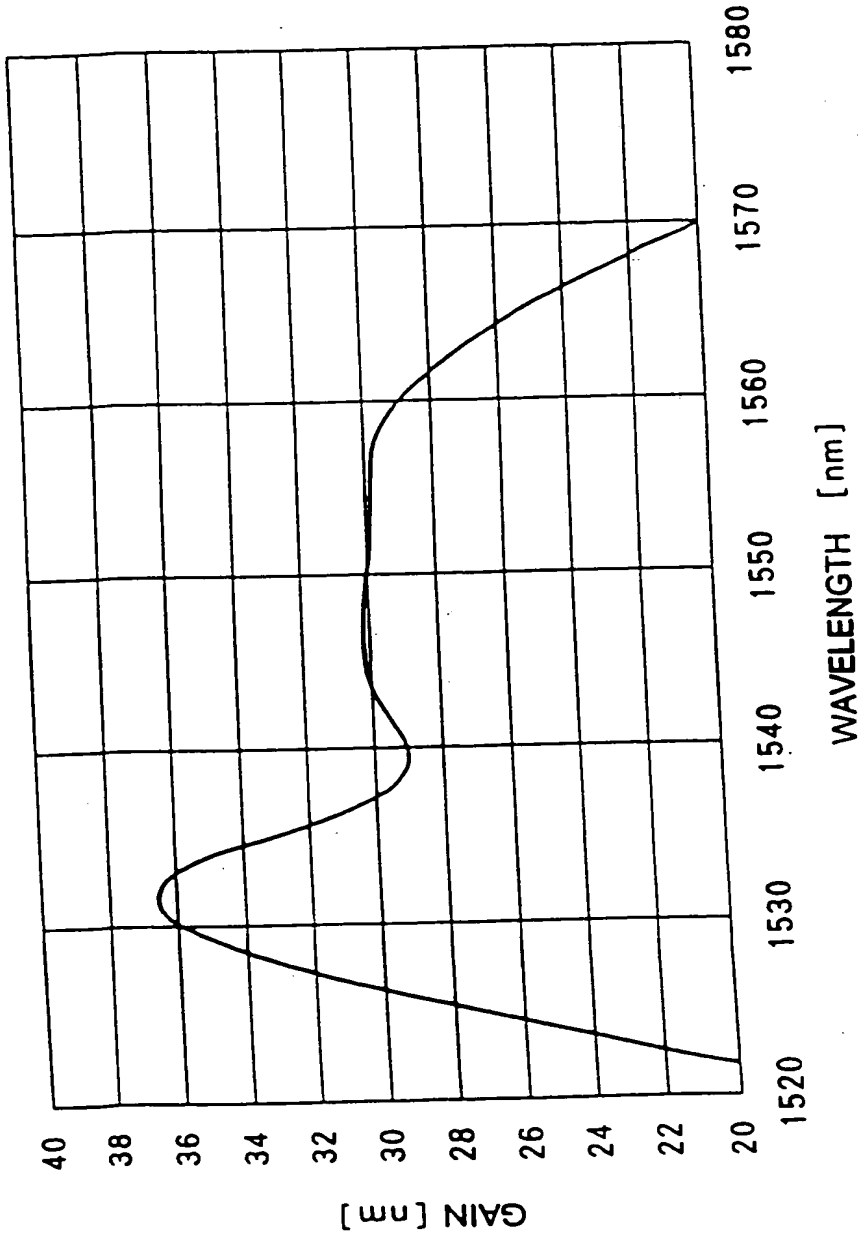

GAIN [nm]
40
38
36
34
32
30
28
26
24
22
20
WAVELENGTH [nm]
1520
1530
1540
1550
1560
1570
1580

FIG. 23

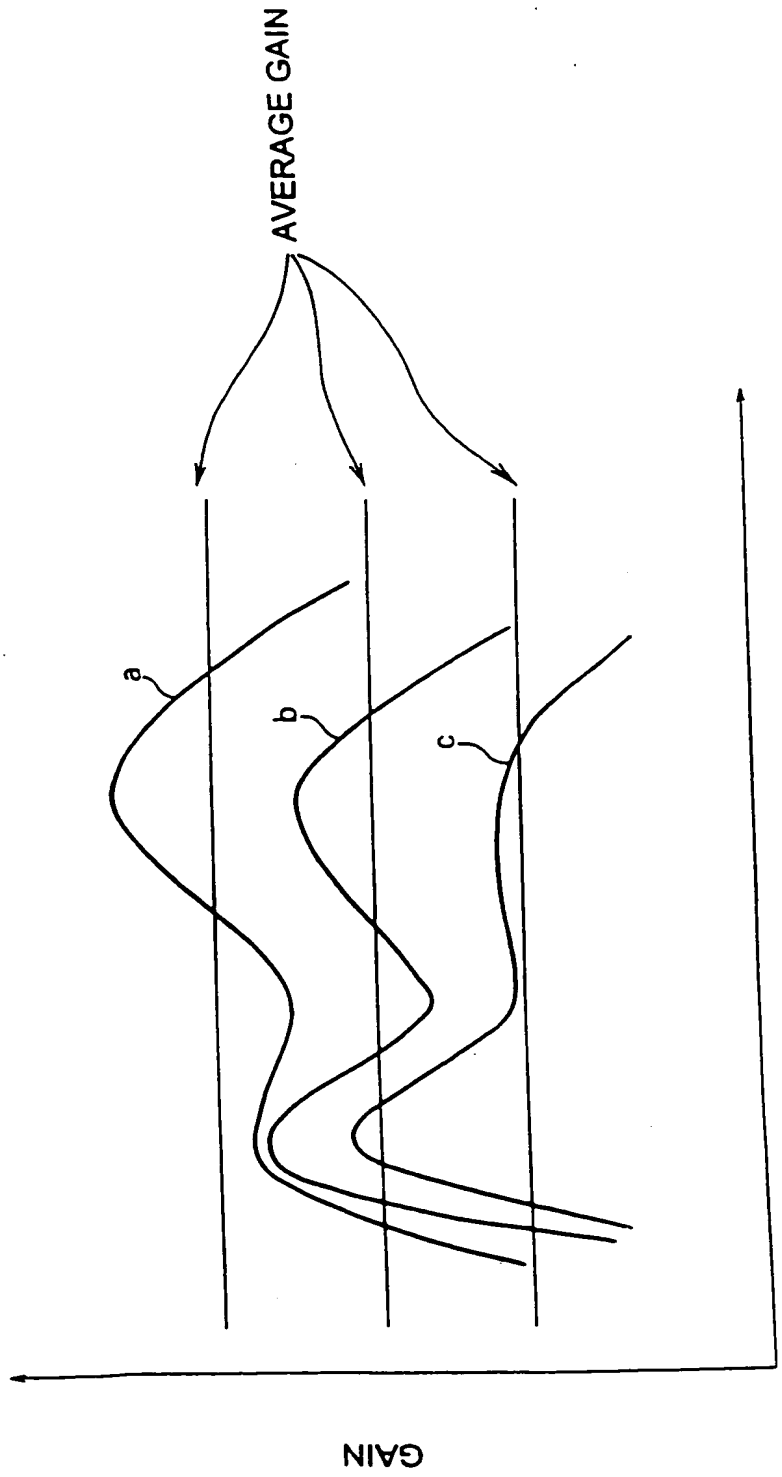


FIG. 24

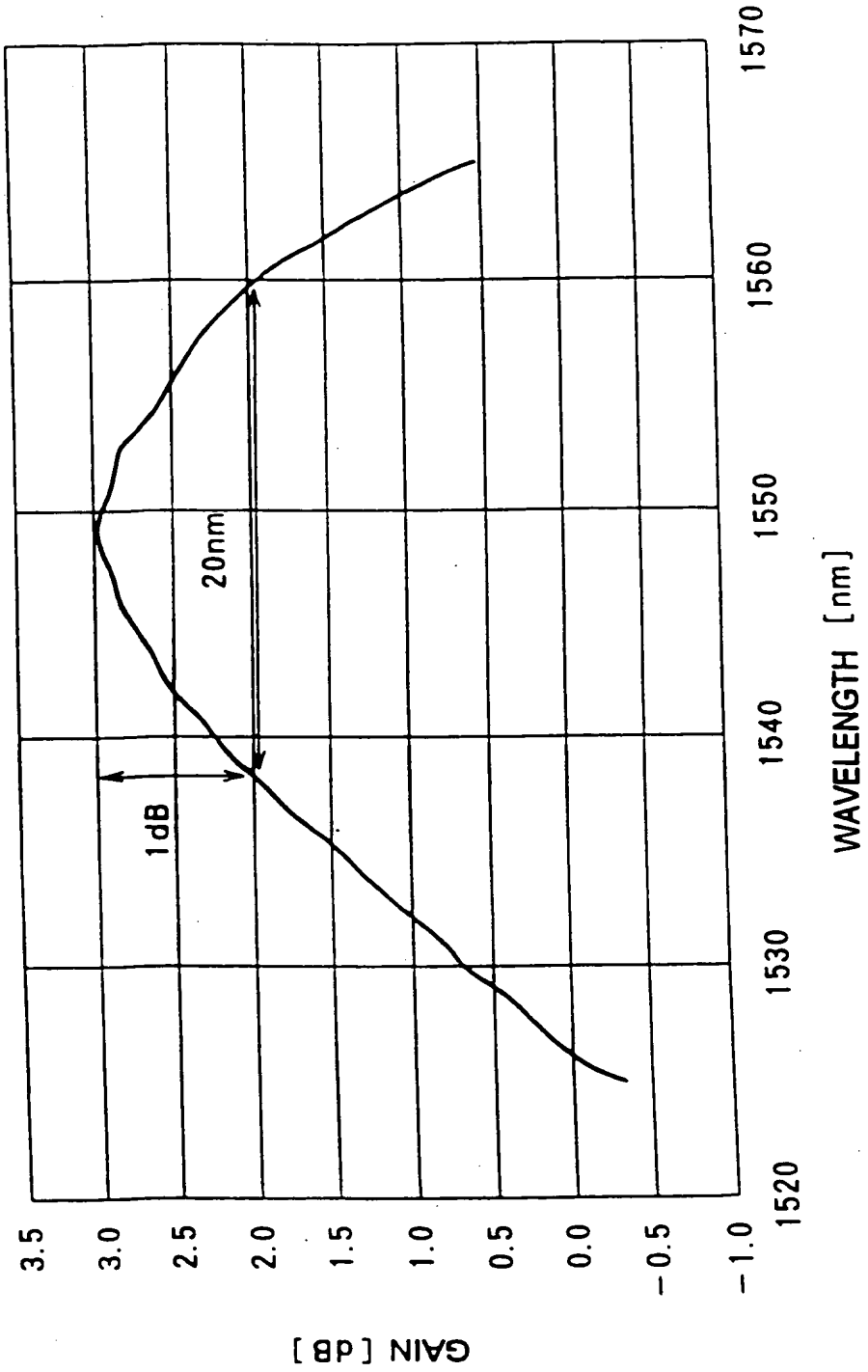

GAIN [dB]
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
1520
1530
1540
1550
1560
1570
WAVELENGTH [nm]
20nm
1dB

FIG. 25

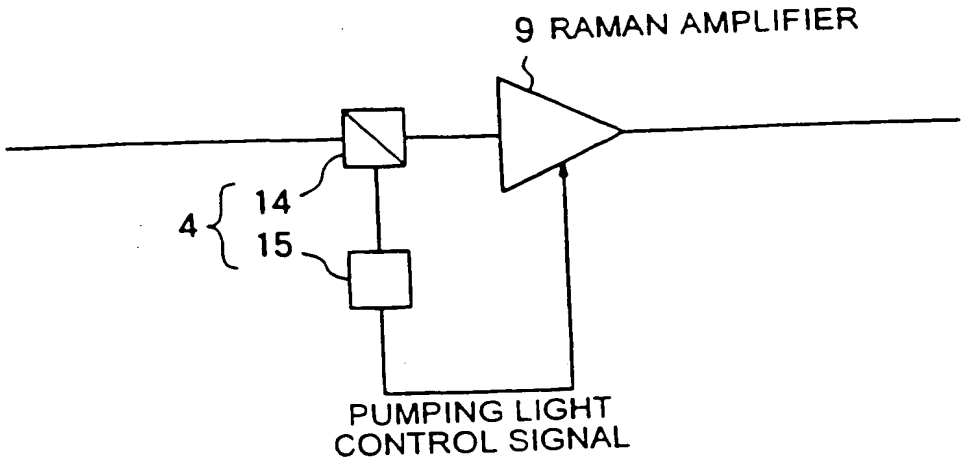

9 RAMAN AMPLIFIER
4
14
15
PUMPING LIGHT
CONTROL SIGNAL

FIG. 26

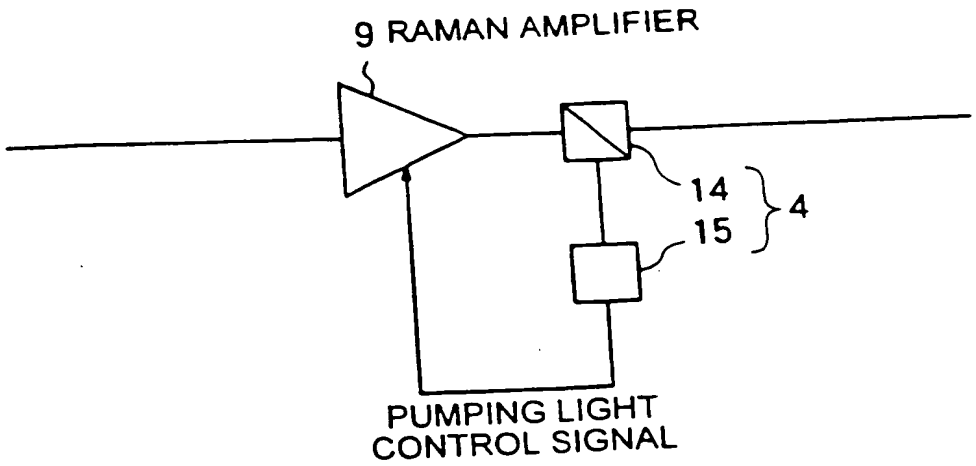

9 RAMAN AMPLIFIER
14
15
4
PUMPING LIGHT
CONTROL SIGNAL

FIG. 27

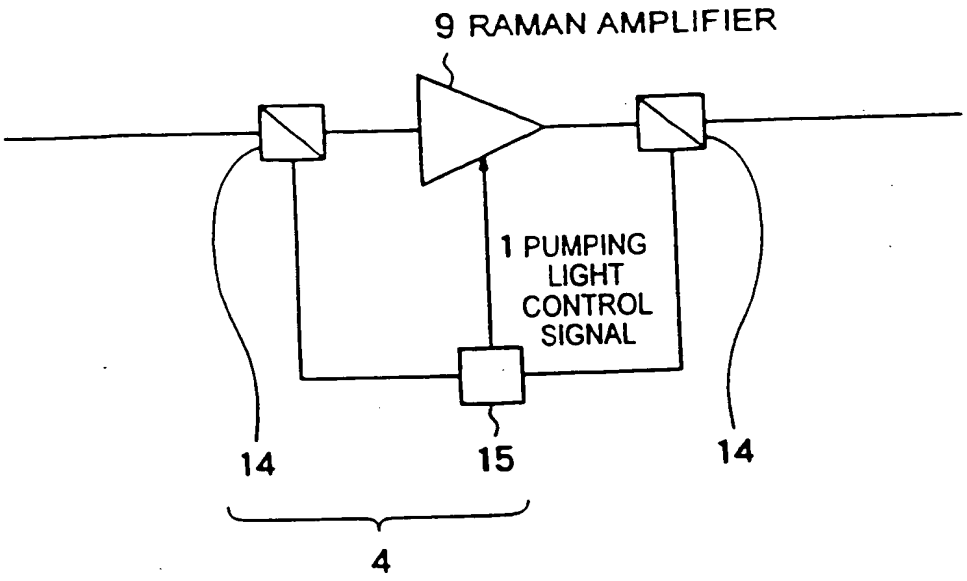


FIG. 28

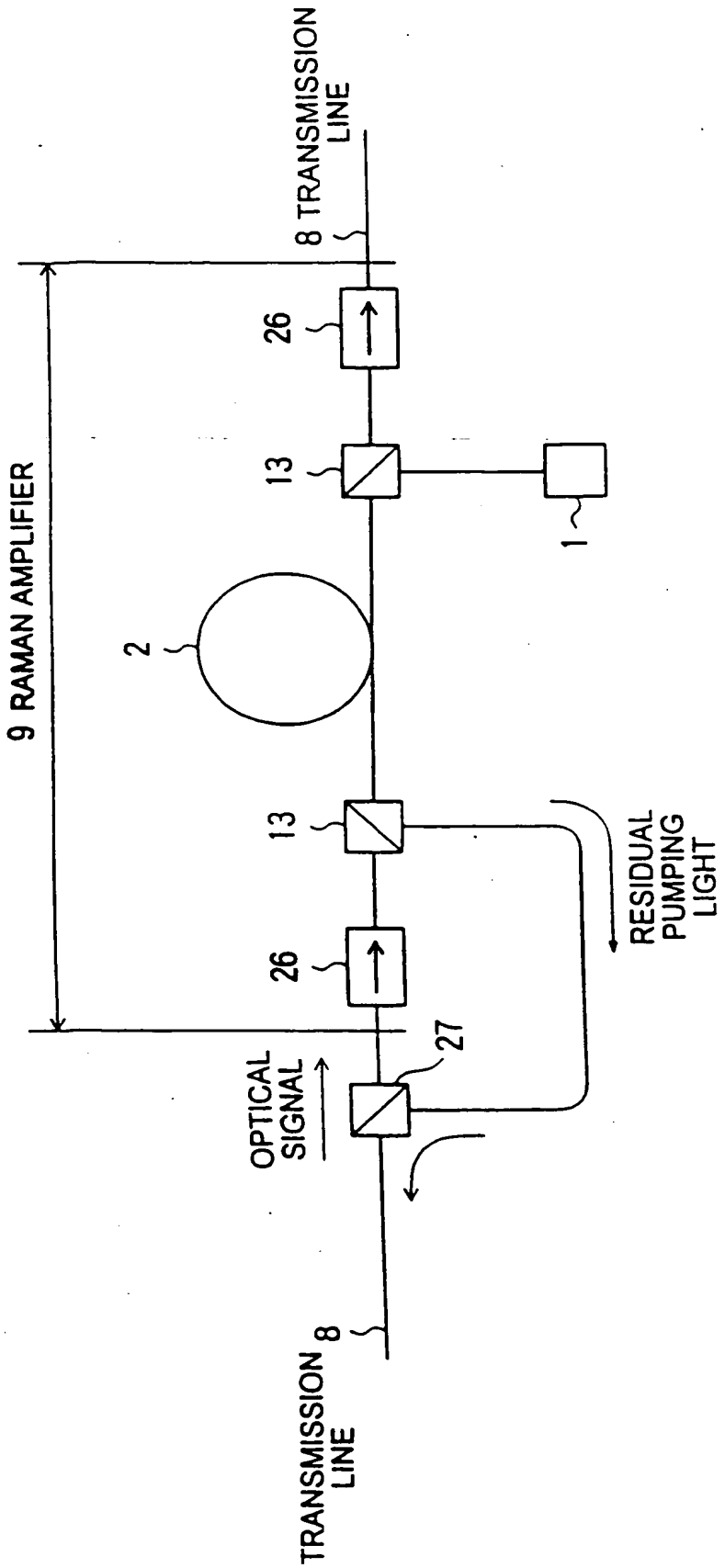

8 TRANSMISSION LINE
26
13
1
2
9 RAMAN AMPLIFIER
13
RESIDUAL PUMPING LIGHT
26
27
OPTICAL SIGNAL
8
TRANSMISSION LINE

FIG. 29

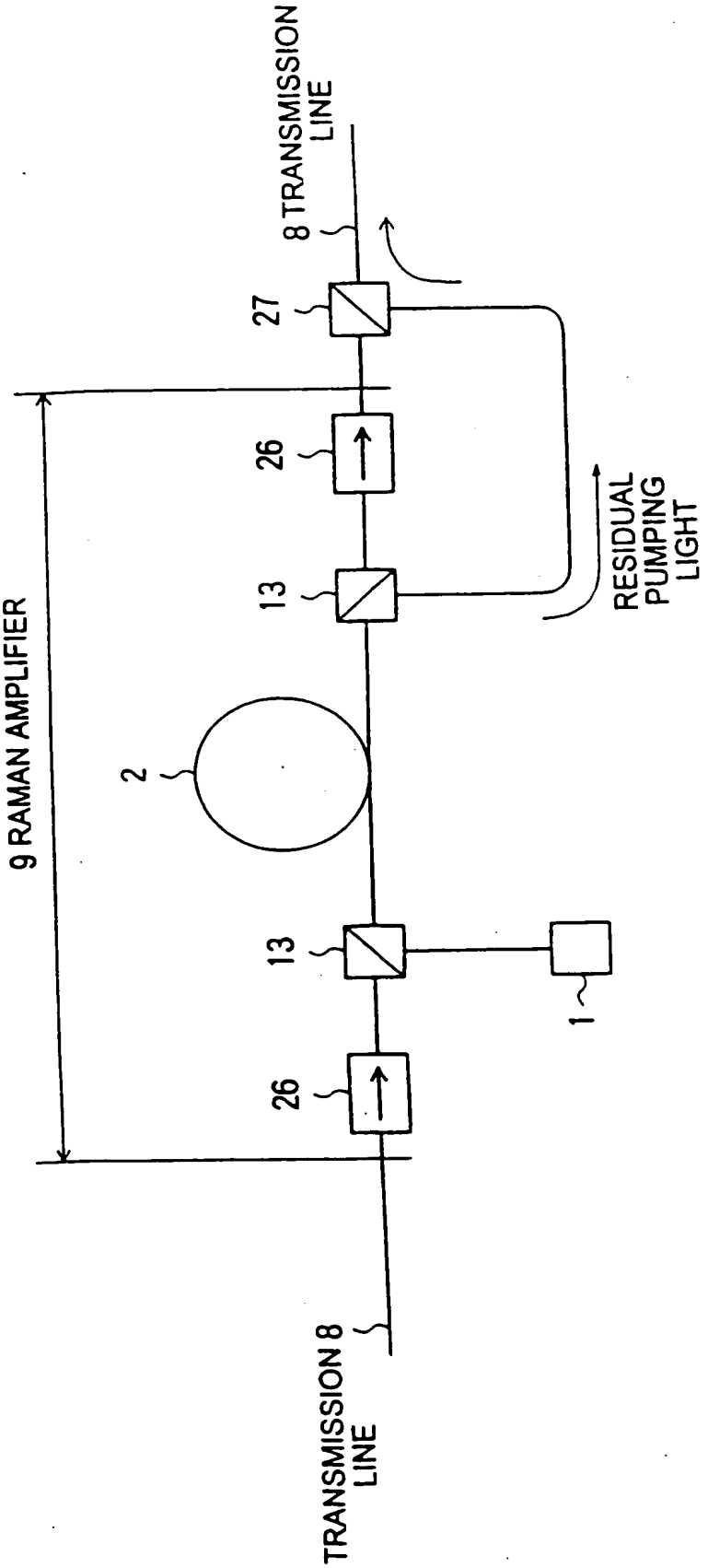

8 TRANSMISSION LINE
27
26
13
RESIDUAL PUMPING LIGHT
9 RAMAN AMPLIFIER
2
13
1
26
TRANSMISSION 8 LINE

FIG. 30

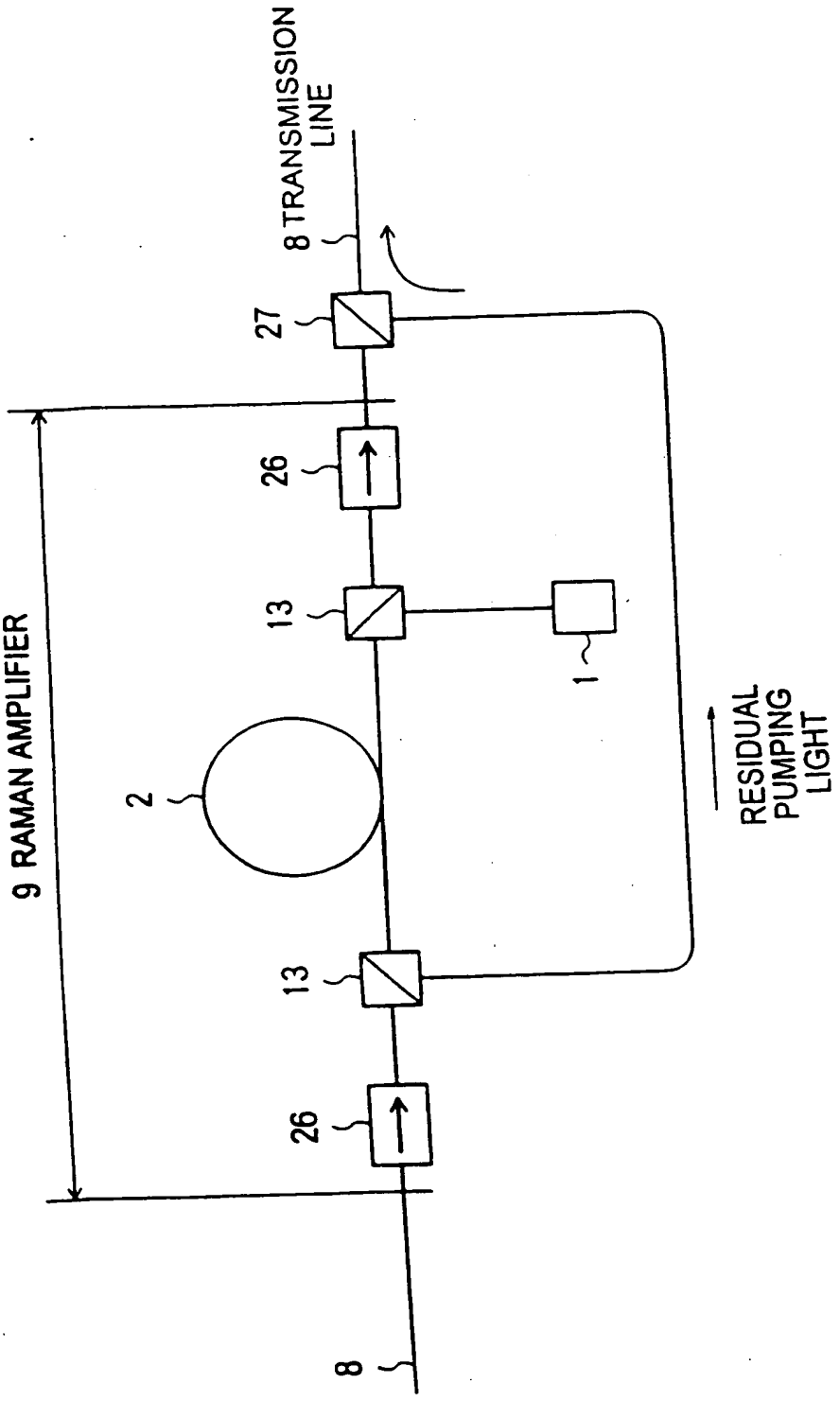

8 TRANSMISSION LINE
27
26
13
1
2
9 RAMAN AMPLIFIER
RESIDUAL PUMPING LIGHT
13
26
8

FIG. 31

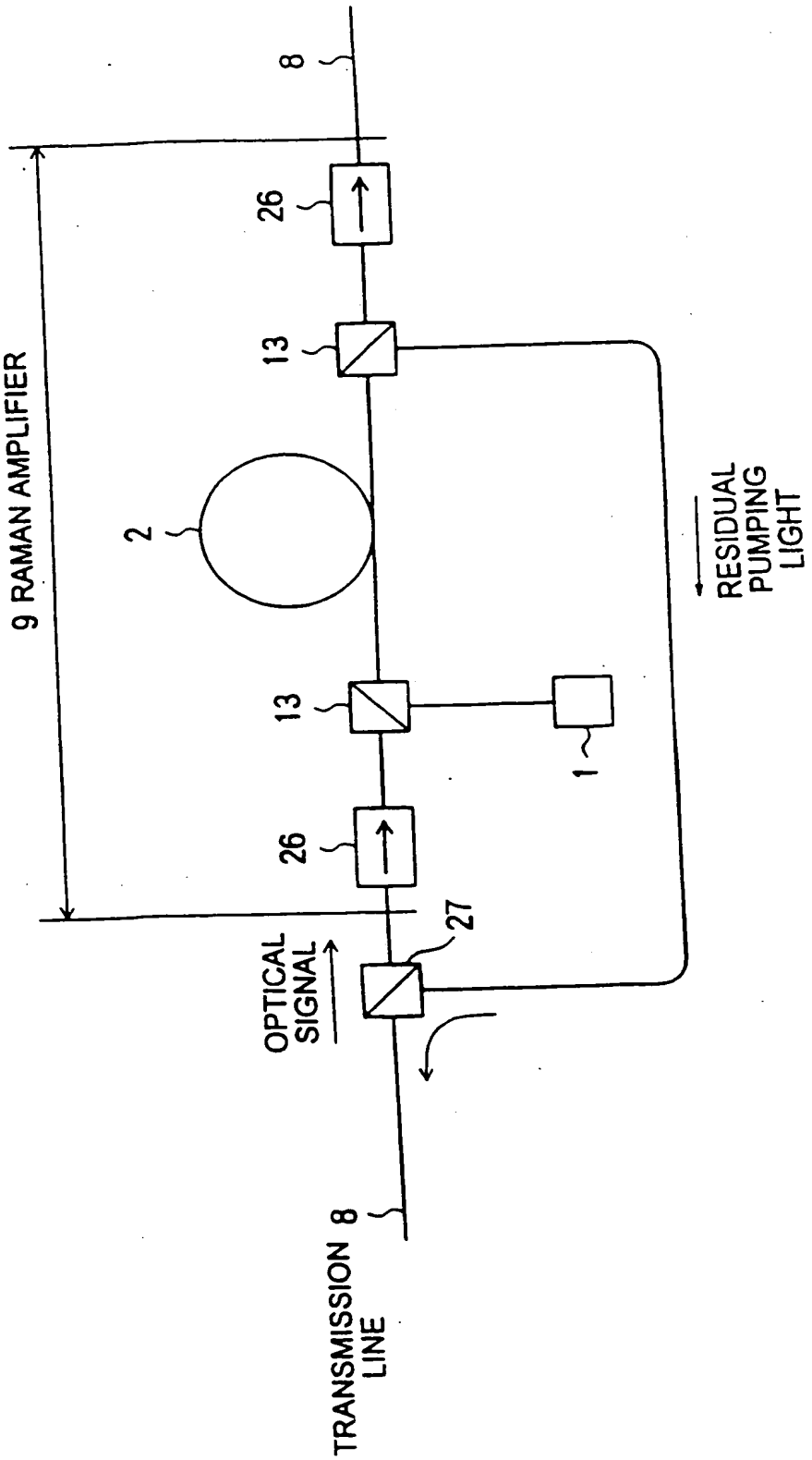

8
26
13
2
9 RAMAN AMPLIFIER
RESIDUAL PUMPING LIGHT
13
1
26
27
OPTICAL SIGNAL
TRANSMISSION LINE 8

FIG. 32

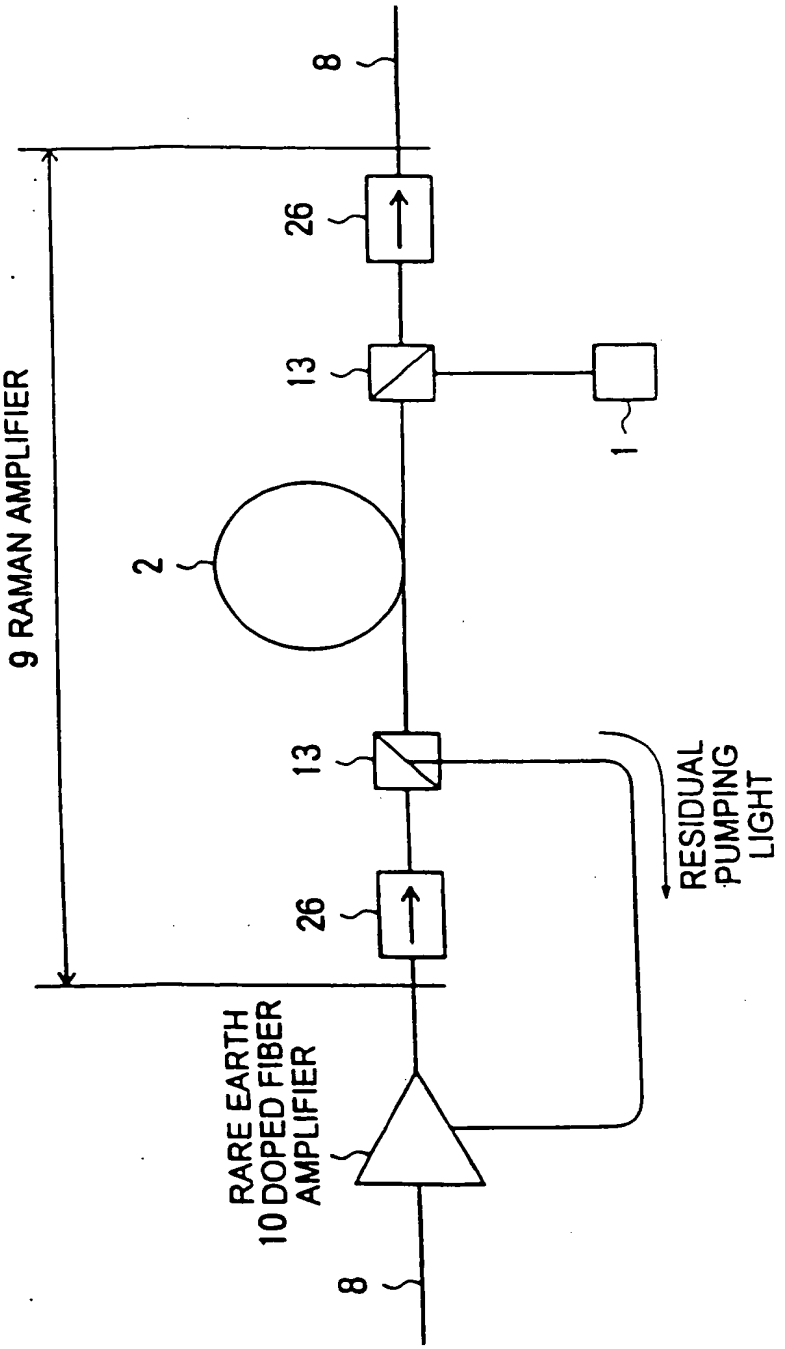

8
26
13
1
2
13
RESIDUAL PUMPING LIGHT
26
9 RAMAN AMPLIFIER
RARE EARTH 10 DOPED FIBER AMPLIFIER
8

FIG. 33

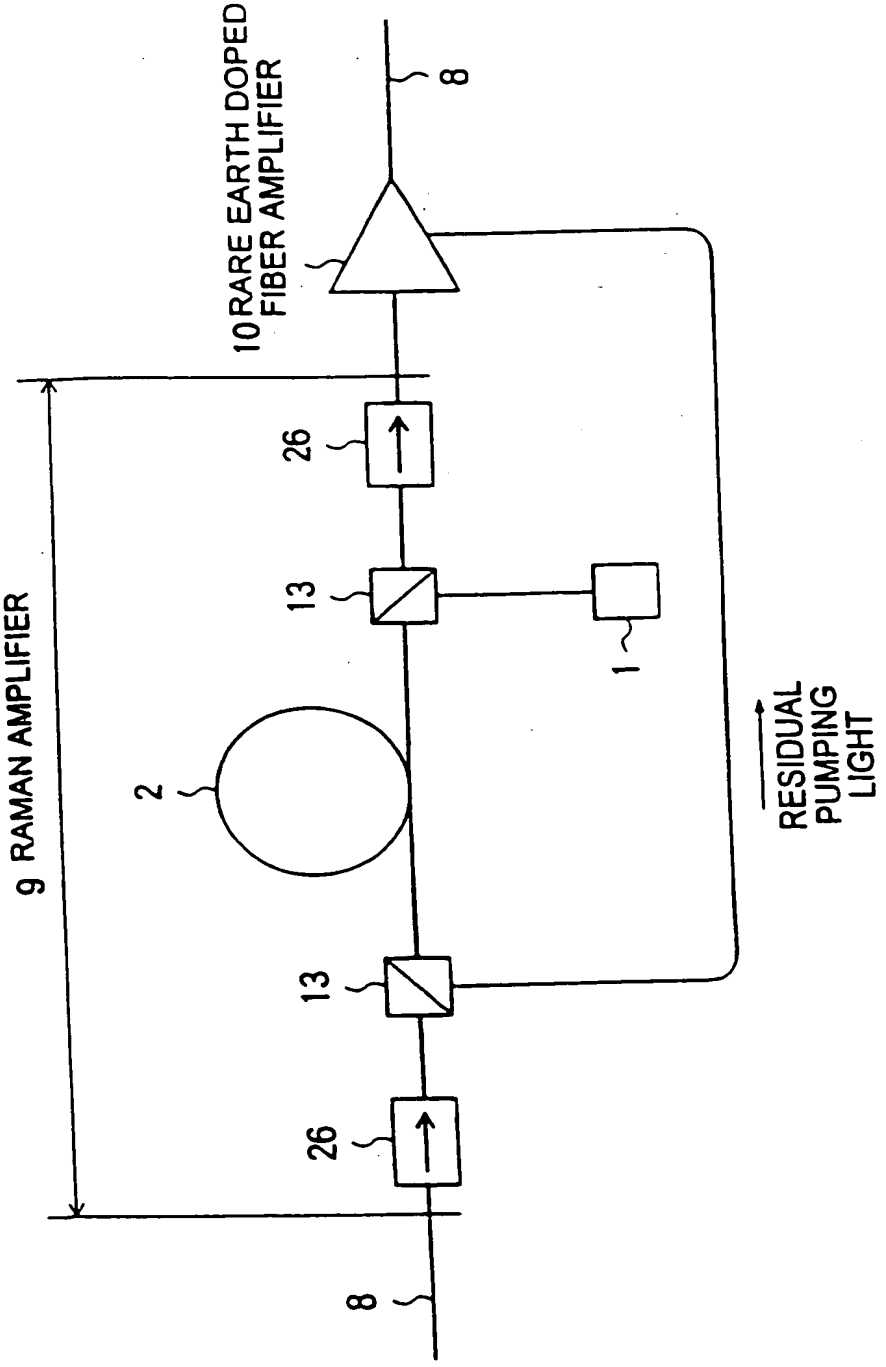

8
10 RARE EARTH DOPED FIBER AMPLIFIER
26
13
1
2
9 RAMAN AMPLIFIER
RESIDUAL PUMPING LIGHT
13
26
8

FIG. 34

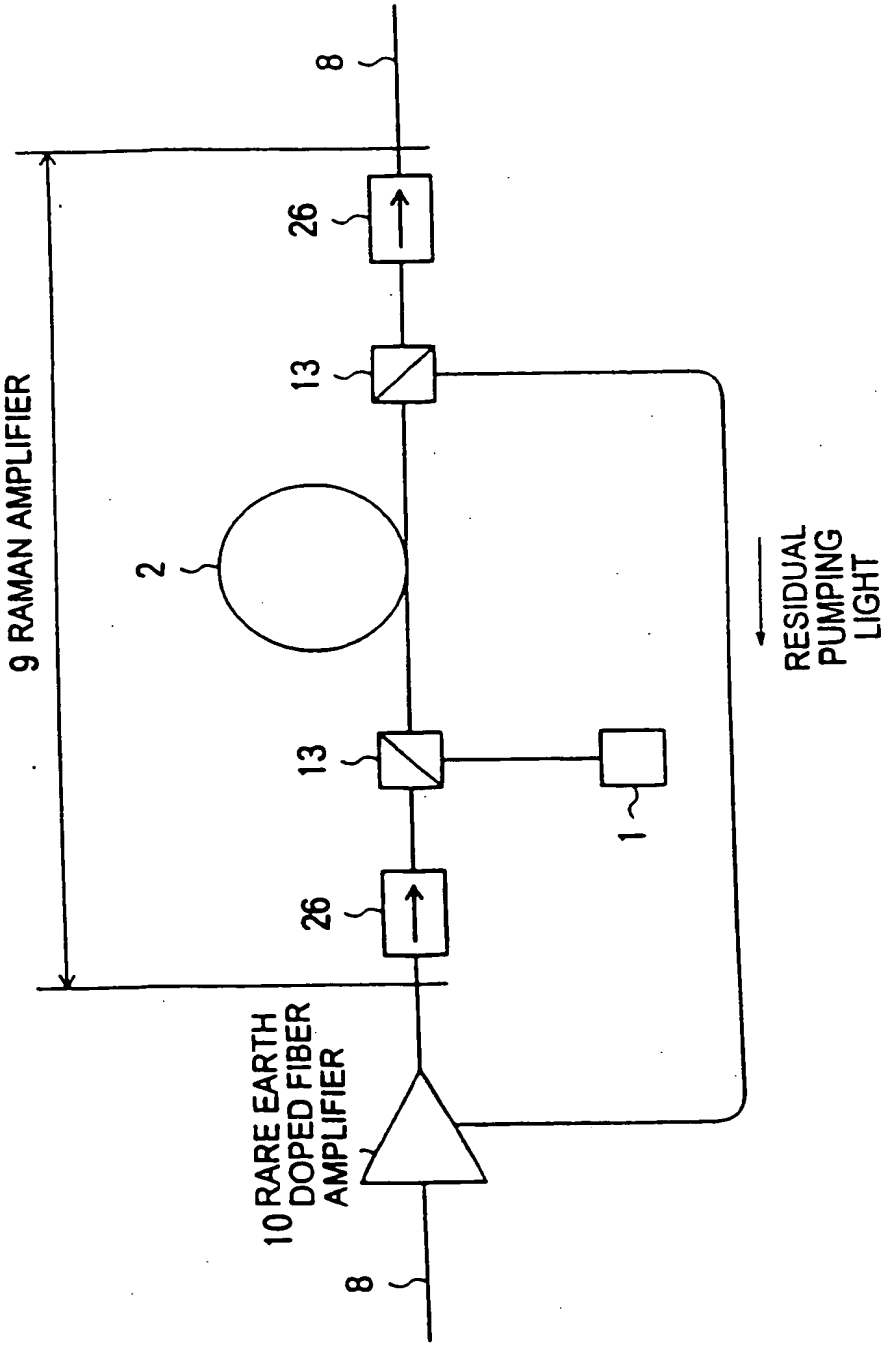

8
26
13
2
13
1
26
9 RAMAN AMPLIFIER
RESIDUAL PUMPING LIGHT
10 RARE EARTH DOPED FIBER AMPLIFIER
8

FIG. 35

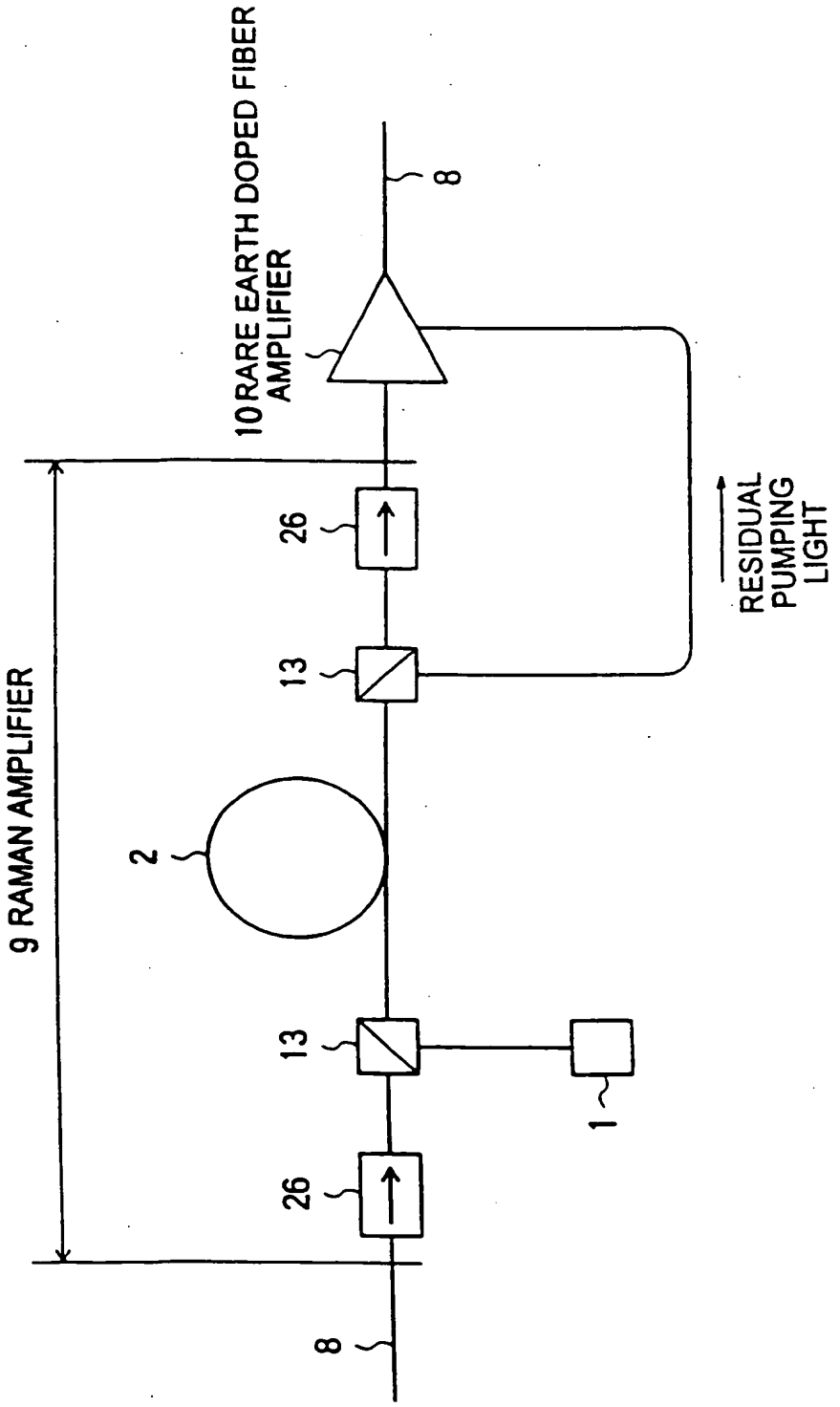

10 RARE EARTH DOPED FIBER AMPLIFIER
8
26
13
RESIDUAL PUMPING LIGHT
9 RAMAN AMPLIFIER
2
13
1
26
8

FIG. 36

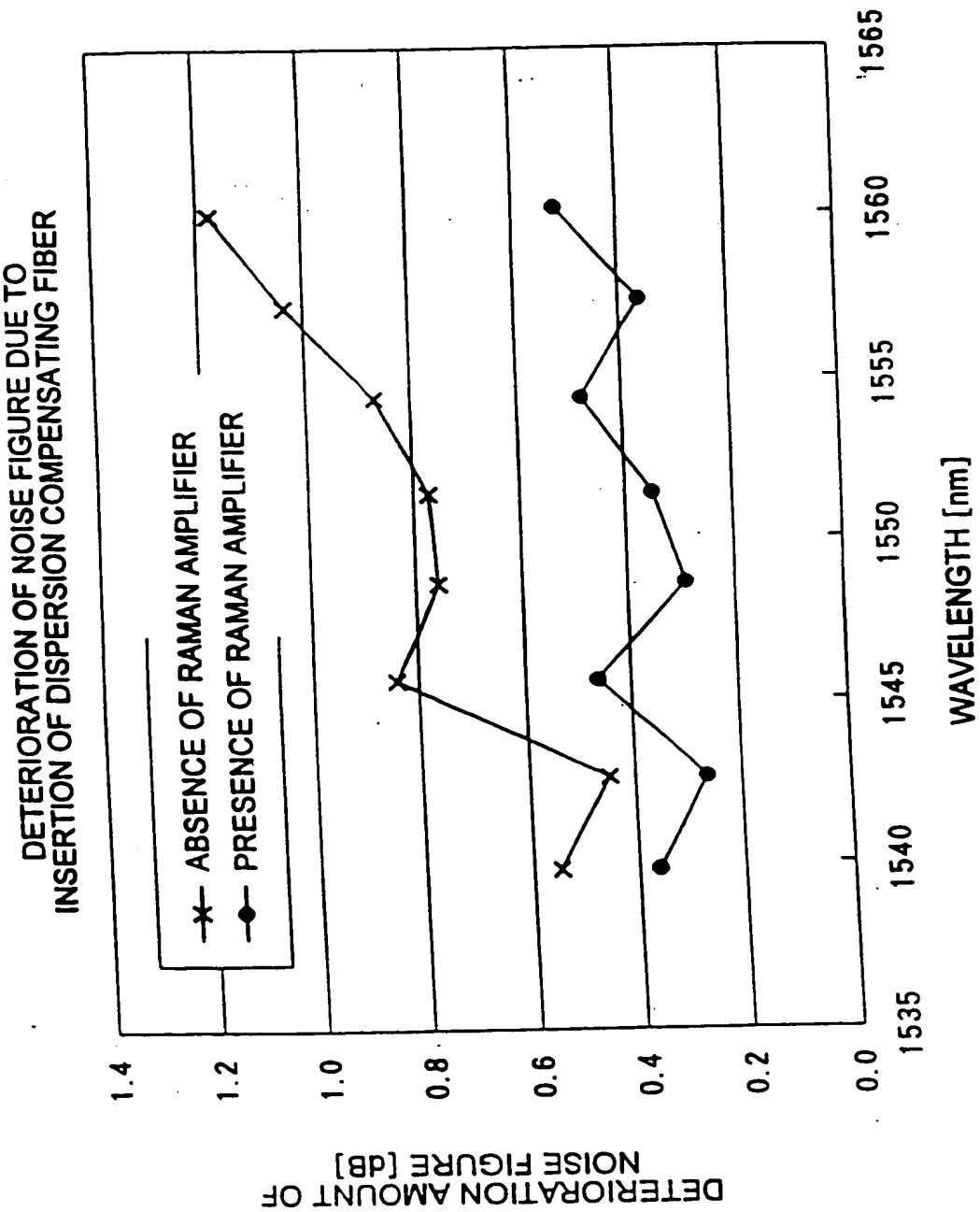

DETERIORATION OF NOISE FIGURE DUE TO INSERTION OF DISPERSION COMPENSATING FIBER
ABSENCE OF RAMAN AMPLIFIER
PRESENCE OF RAMAN AMPLIFIER
DETERIORATION AMOUNT OF NOISE FIGURE [dB]
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1535
1540
1545
1550
1555
1560
1565
WAVELENGTH [nm]

FIG. 37

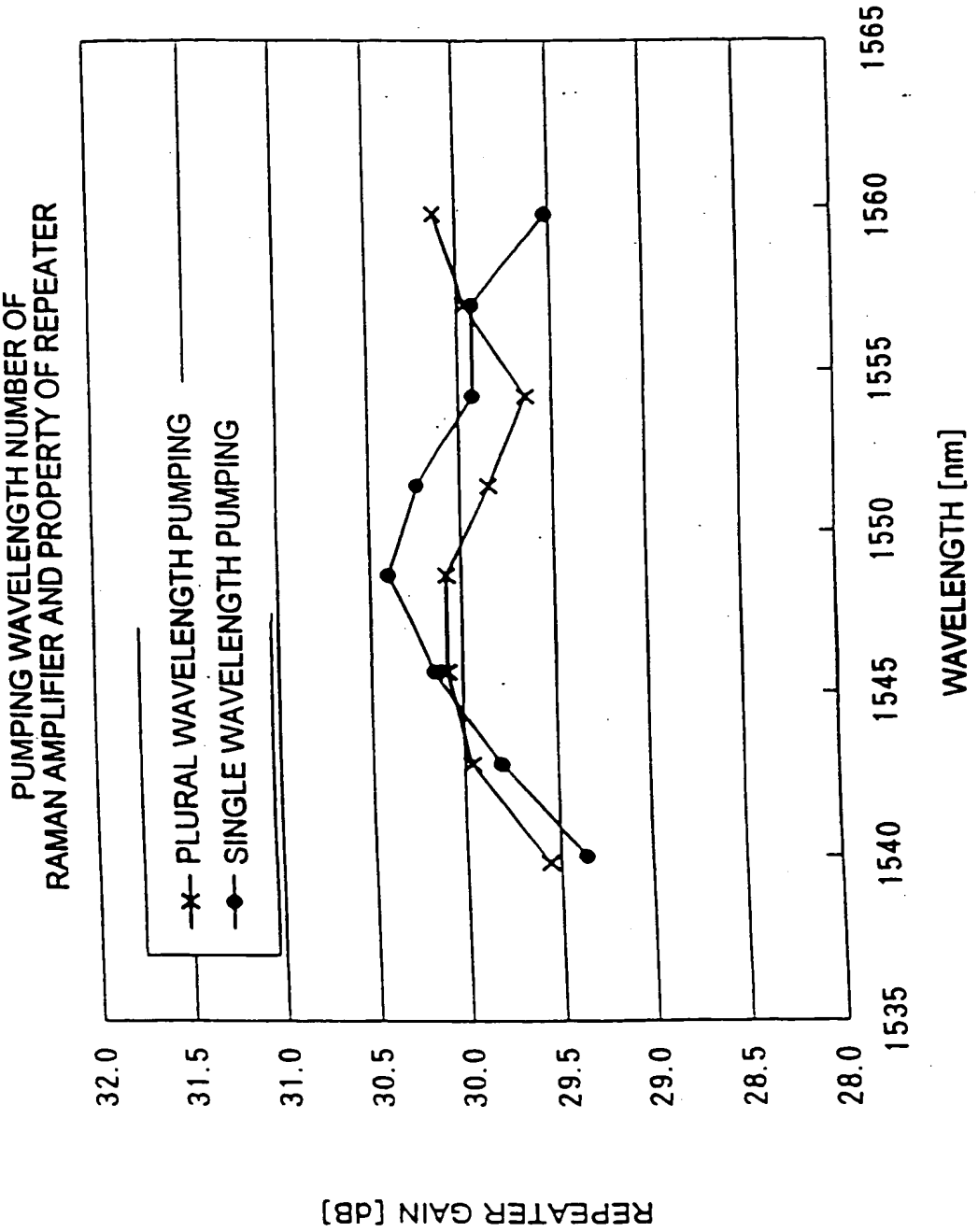

PUMPING WAVELENGTH NUMBER OF
RAMAN AMPLIFIER AND PROPERTY OF REPEATER
PLURAL WAVELENGTH PUMPING
SINGLE WAVELENGTH PUMPING
REPEATER GAIN [dB]
32.0
31.5
31.0
30.5
30.0
29.5
29.0
28.5
28.0
1535
1540
1545
1550
1555
1560
1565
WAVELENGTH [nm]

FIG. 38

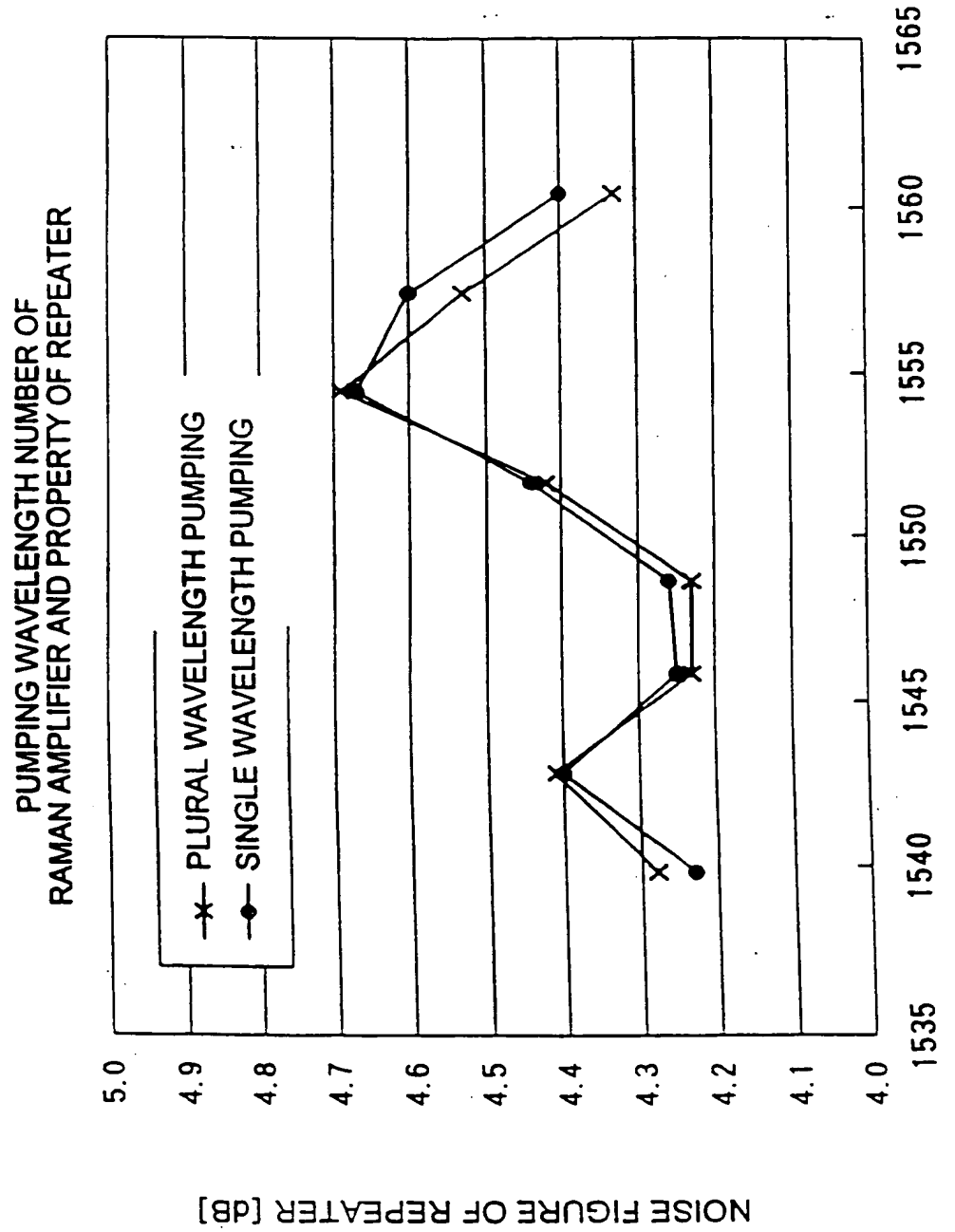

PUMPING WAVELENGTH NUMBER OF
RAMAN AMPLIFIER AND PROPERTY OF REPEATER
PLURAL WAVELENGTH PUMPING
SINGLE WAVELENGTH PUMPING
NOISE FIGURE OF REPEATER [dB]
5.0
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4.0
1535
1540
1545
1550
1555
1560
1565
WAVELENGTH [nm]

FIG. 39

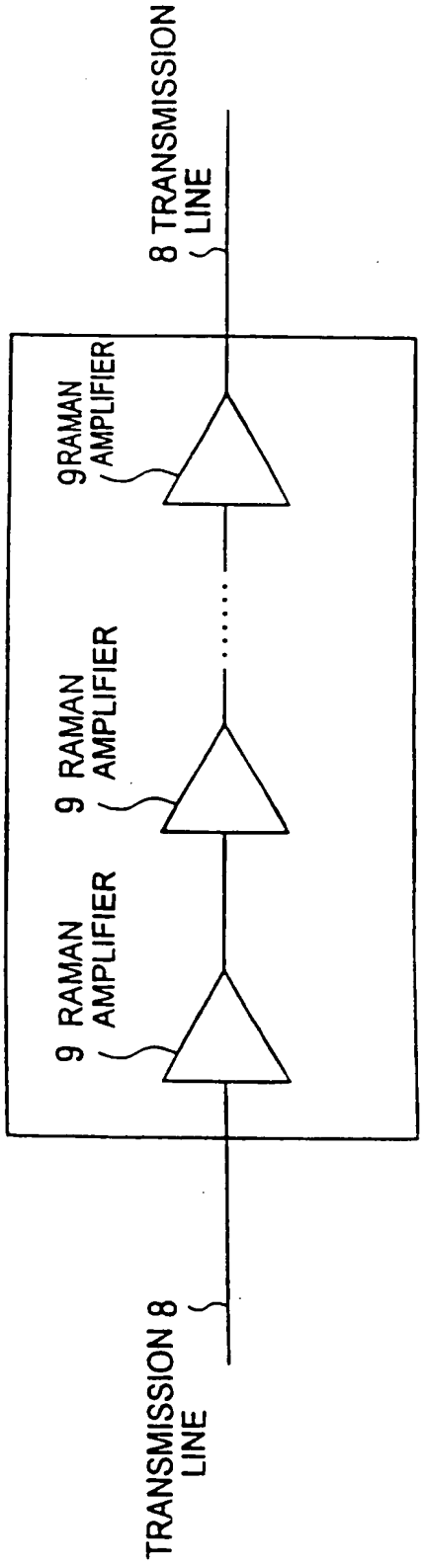

8 TRANSMISSION LINE
9RAMAN AMPLIFIER
9 RAMAN AMPLIFIER
9 RAMAN AMPLIFIER
TRANSMISSION 8 LINE

FIG. 40

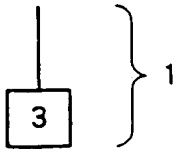


FIG. 41

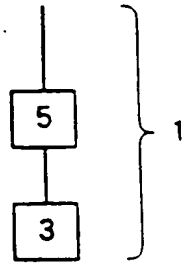


FIG. 42

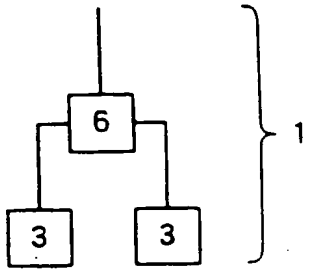


FIG. 43

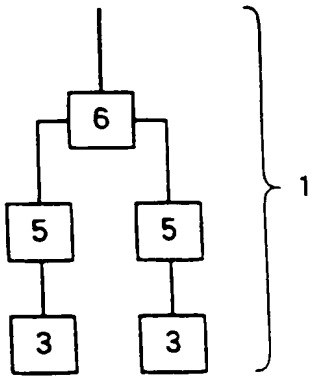


FIG. 44

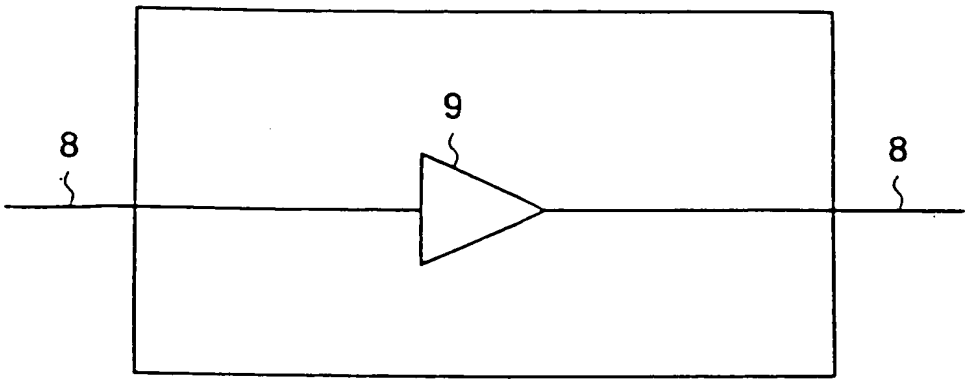


FIG. 45

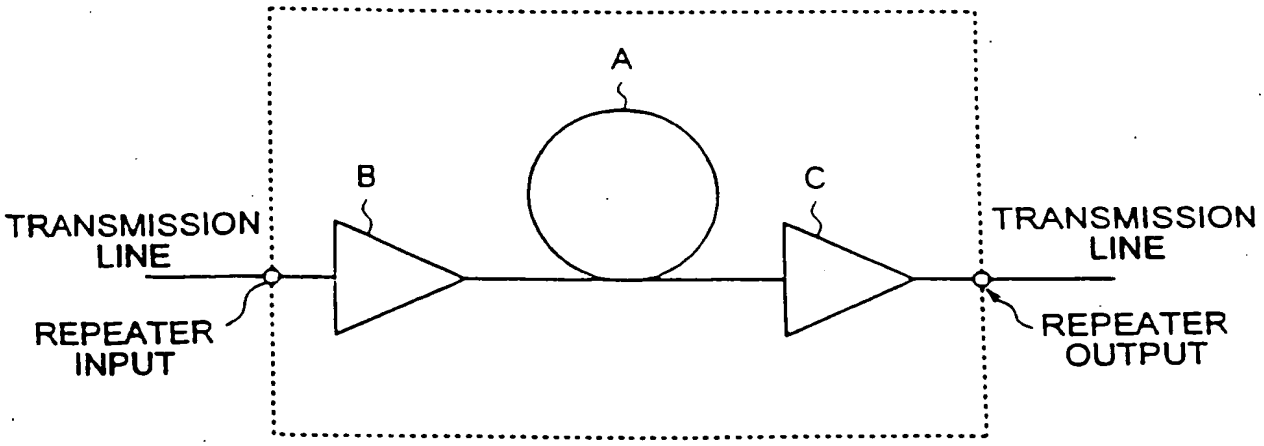


FIG. 46
PRIOR ART

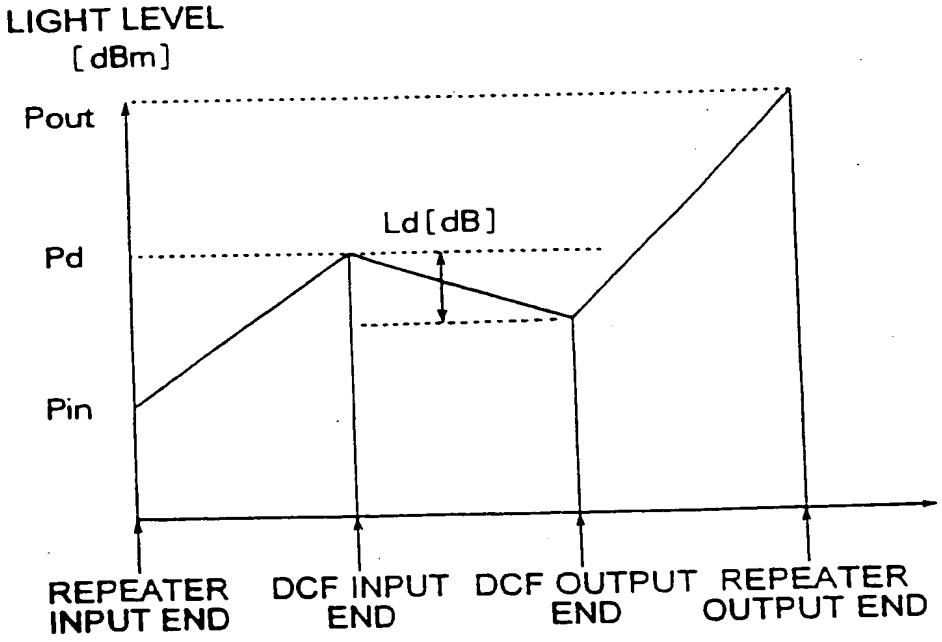

LIGHT LEVEL
[dBm]
Pout
Pd
Pin
Ld[dB]
REPEATER INPUT END
DCF INPUT END
DCF OUTPUT END
REPEATER OUTPUT END

FIG. 47

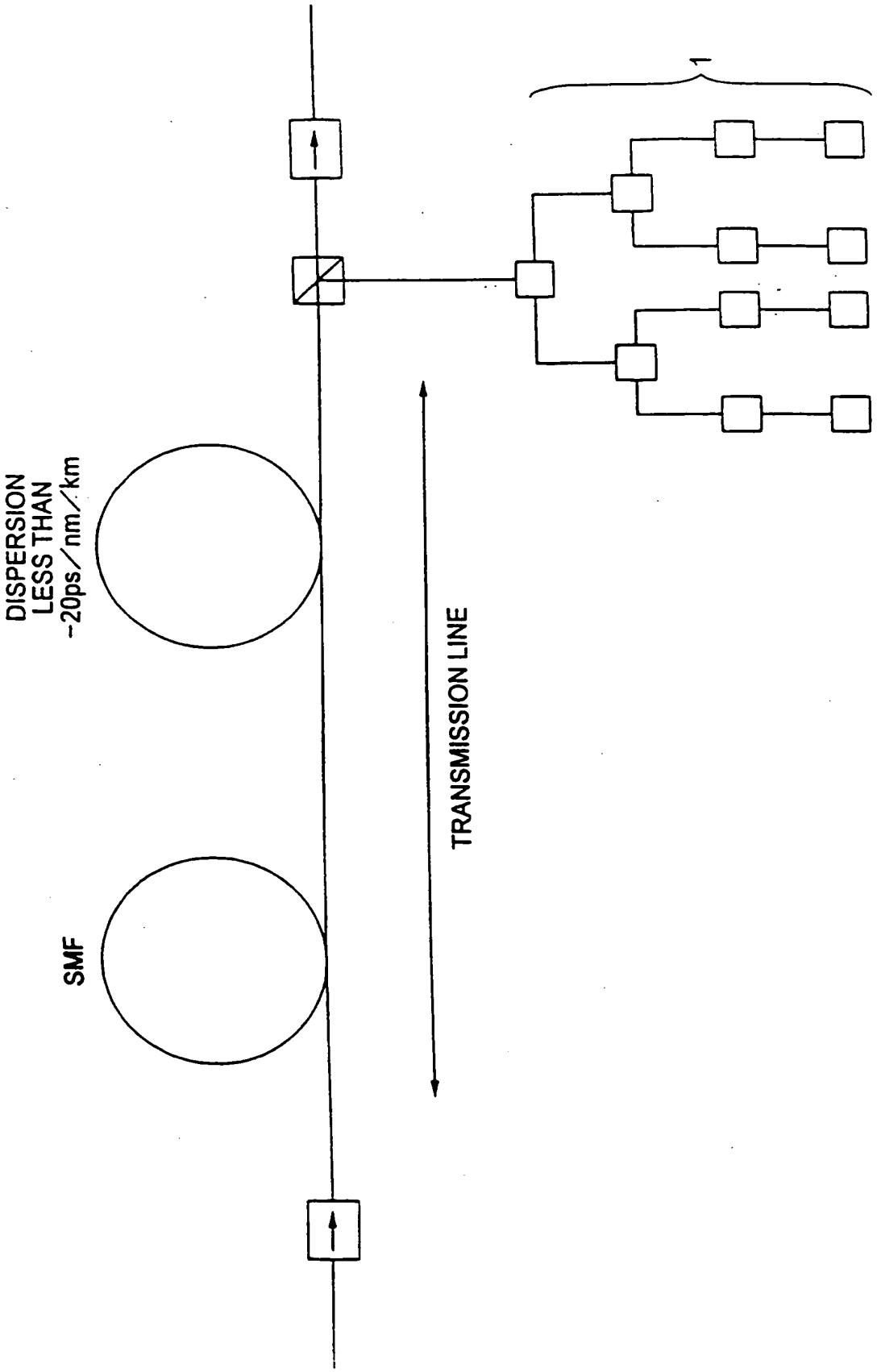


FIG. 48

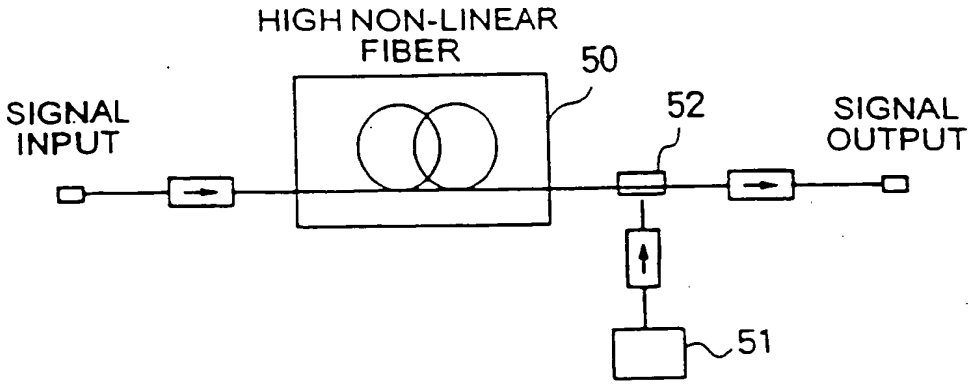

HIGH NON-LINEAR
FIBER
50
SIGNAL
INPUT
52
SIGNAL
OUTPUT
51

FIG. 49

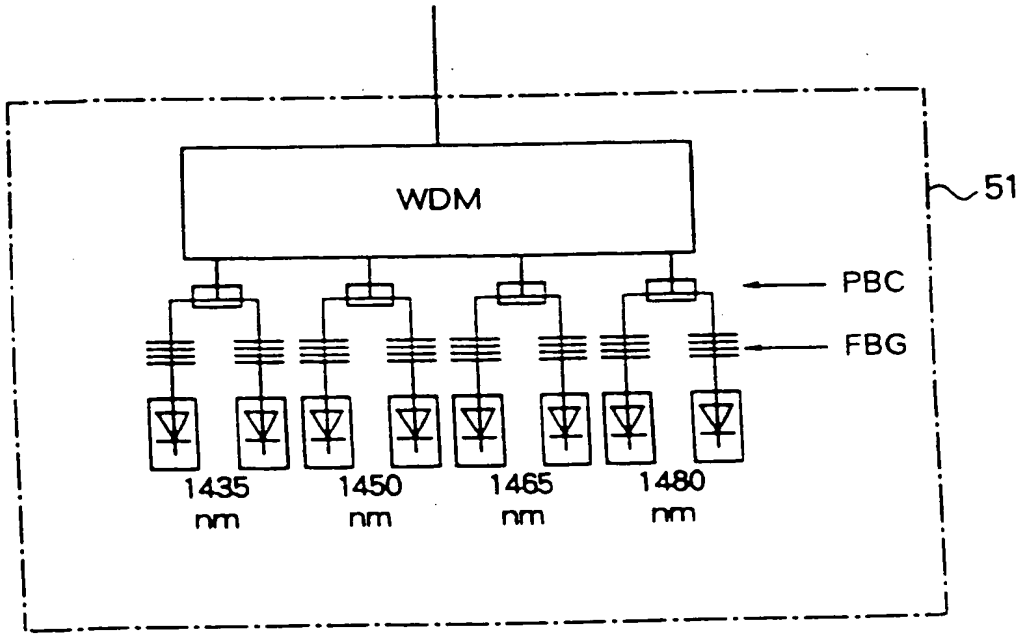

WDM
51
PBC
FBG
1435
nm
1450
nm
1465
nm
1480
nm

FIG. 50

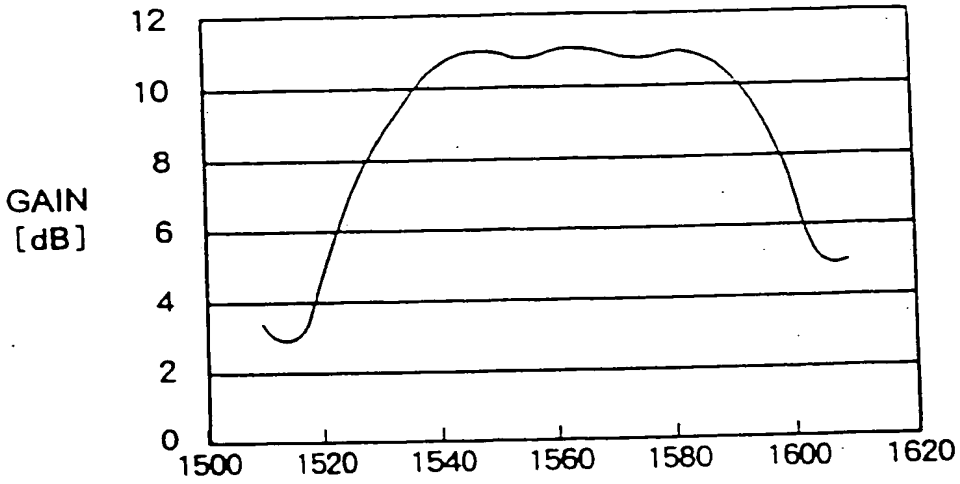

GAIN
[dB]
12
10
8
6
4
2
0
1500
1520
1540
1560
1580
1600
1620

FIG. 51

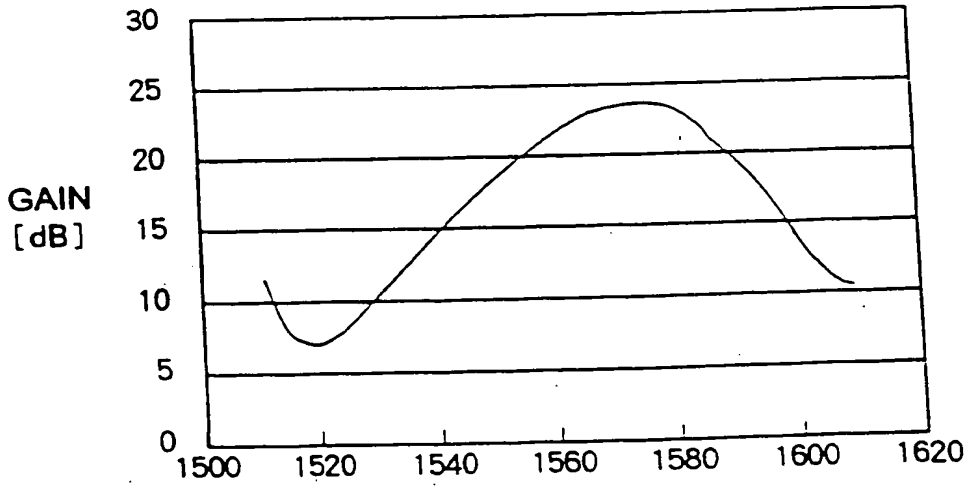

GAIN
[dB]
30
25
20
15
10
5
0
1500
1520
1540
1560
1580
1600
1620

FIG. 52

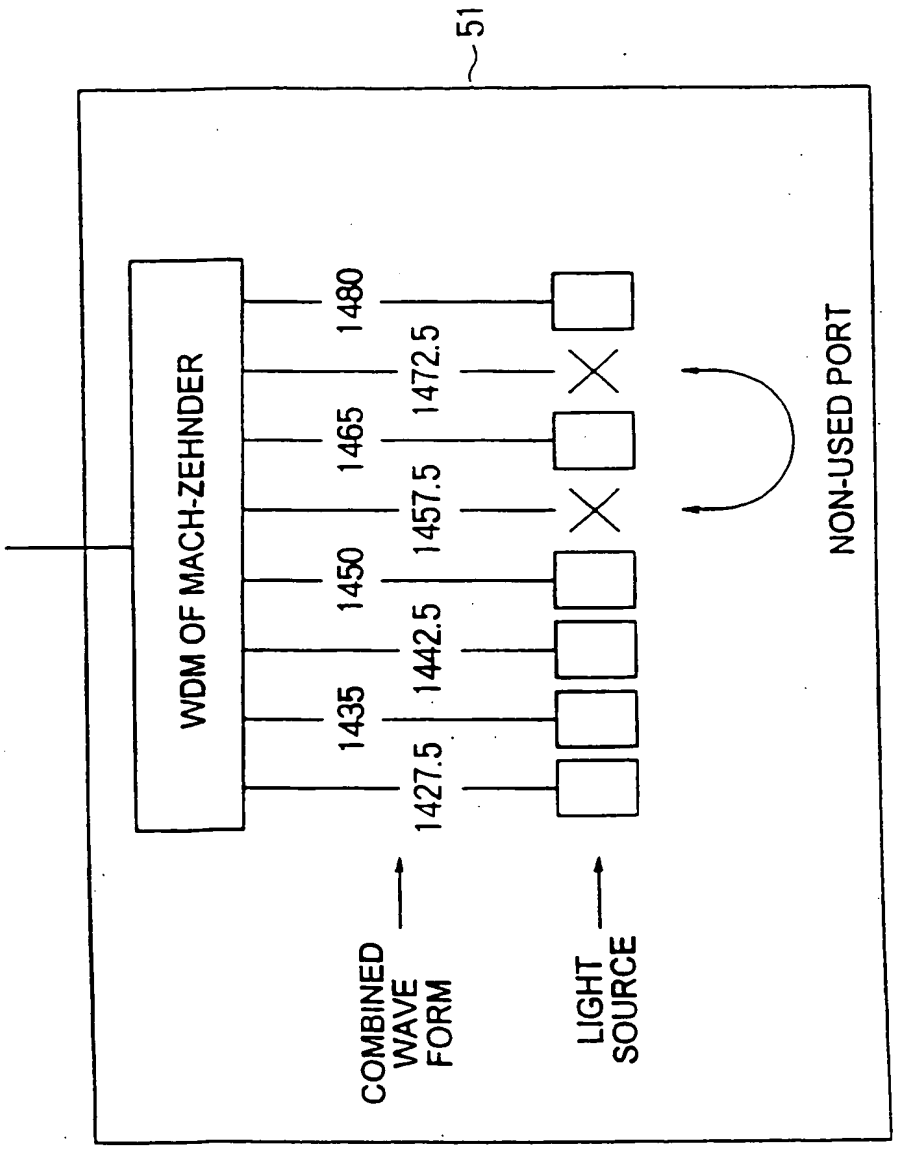

51
WDM OF MACH-ZEHNDER
1480
1472.5
1465
1457.5
1450
1442.5
1435
1427.5
NON-USED PORT
COMBINED WAVE FORM
LIGHT SOURCE

FIG. 53

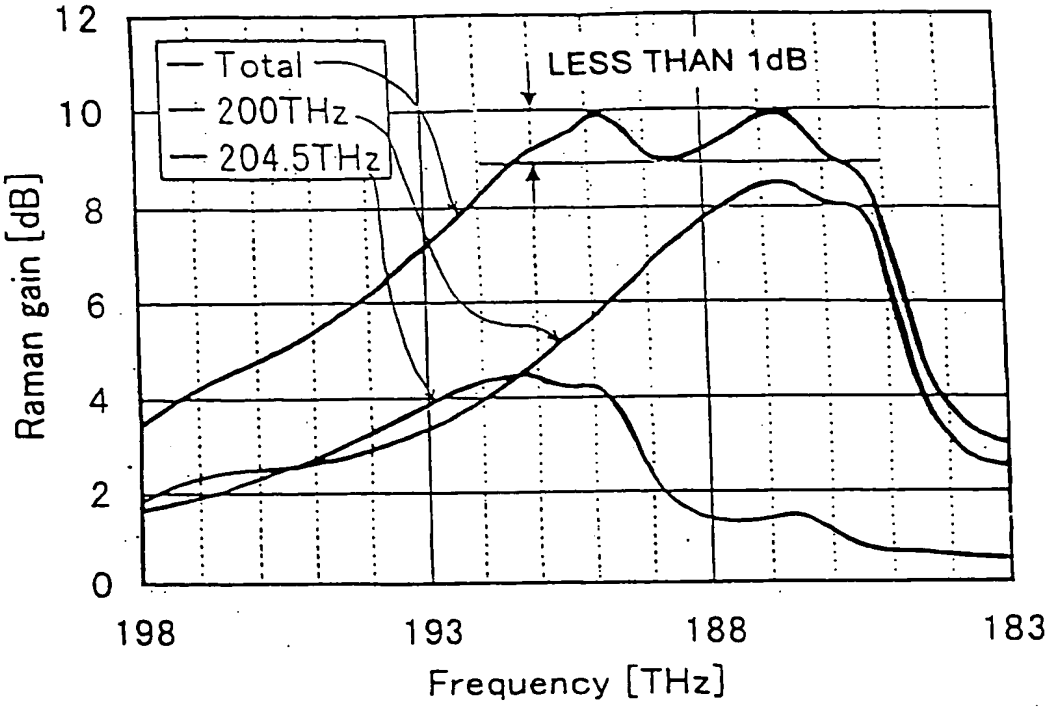


FIG. 54A

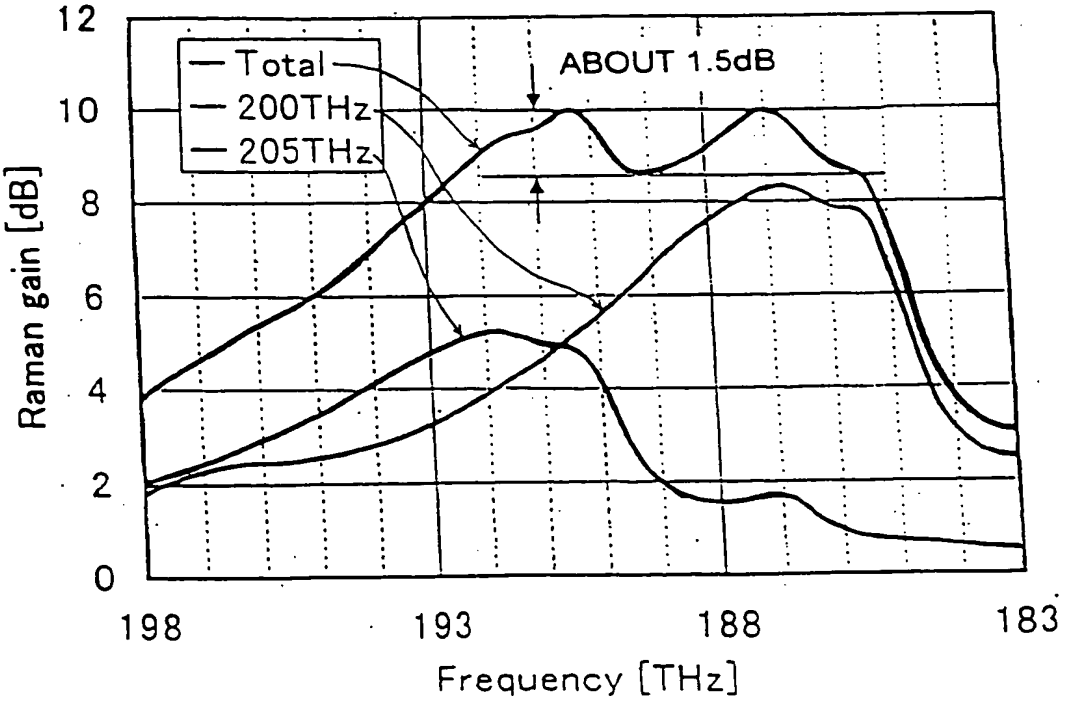


FIG. 54B

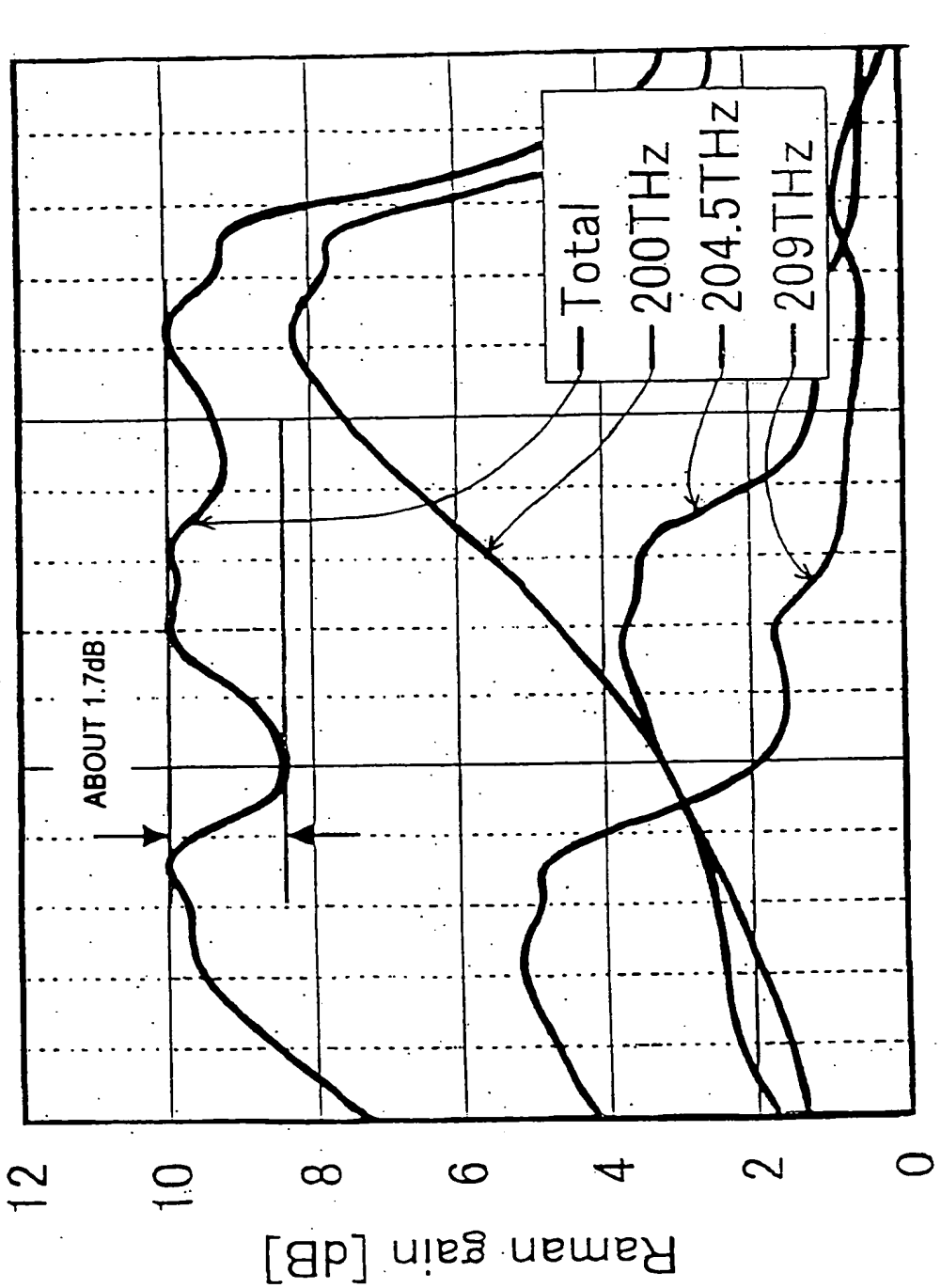

Raman gain [dB]
12
10
8
6
4
2
0
198
193
188
183
Frequency [THz]
Total
200THz
204.5THz
209THz
ABOUT 1.7dB

FIG. 55

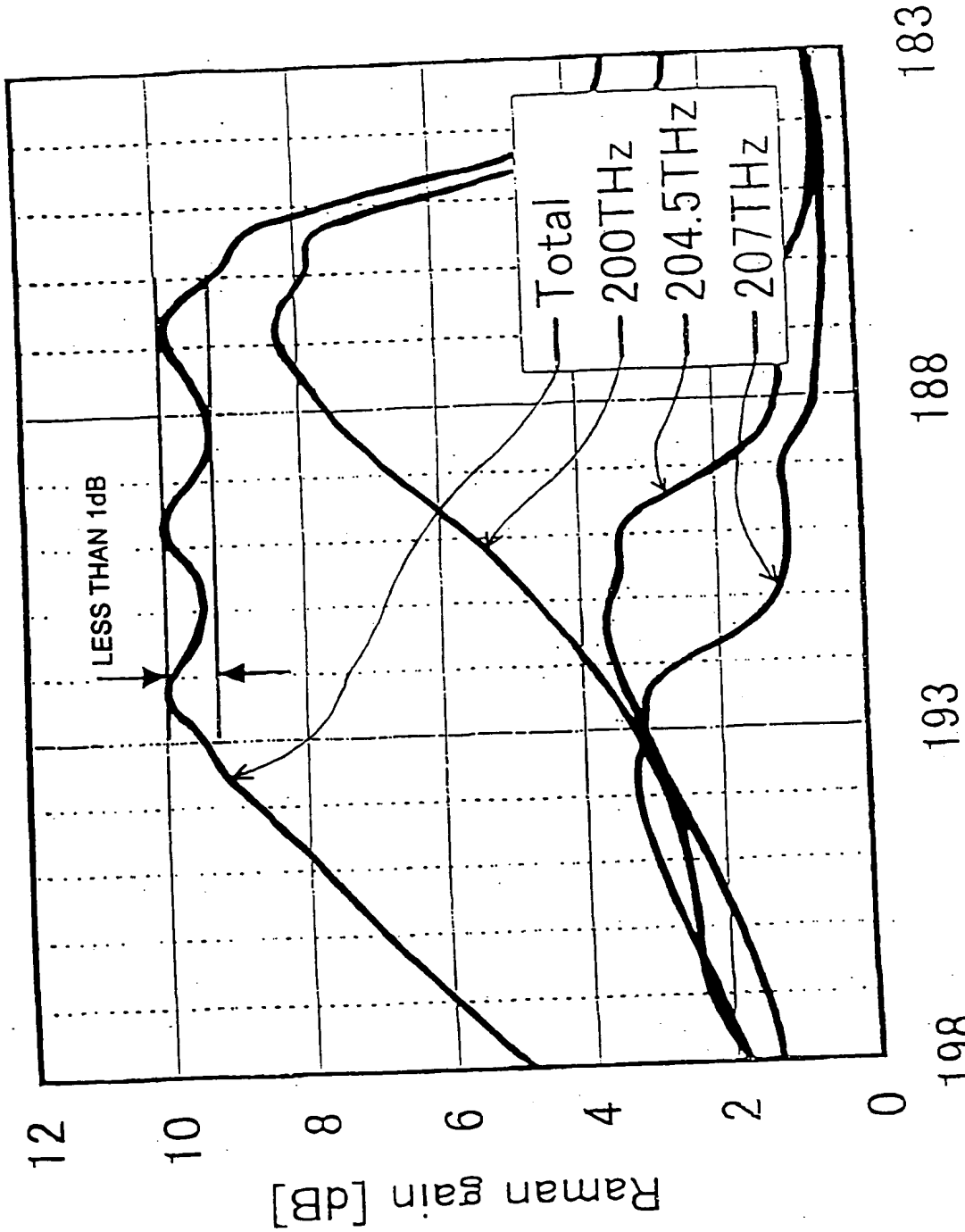

Raman gain [dB]
12
10
8
6
4
2
0
198
193
188
183
Frequency [THz]
Total
200THz
204.5THz
207THz
LESS THAN 1dB

FIG. 56

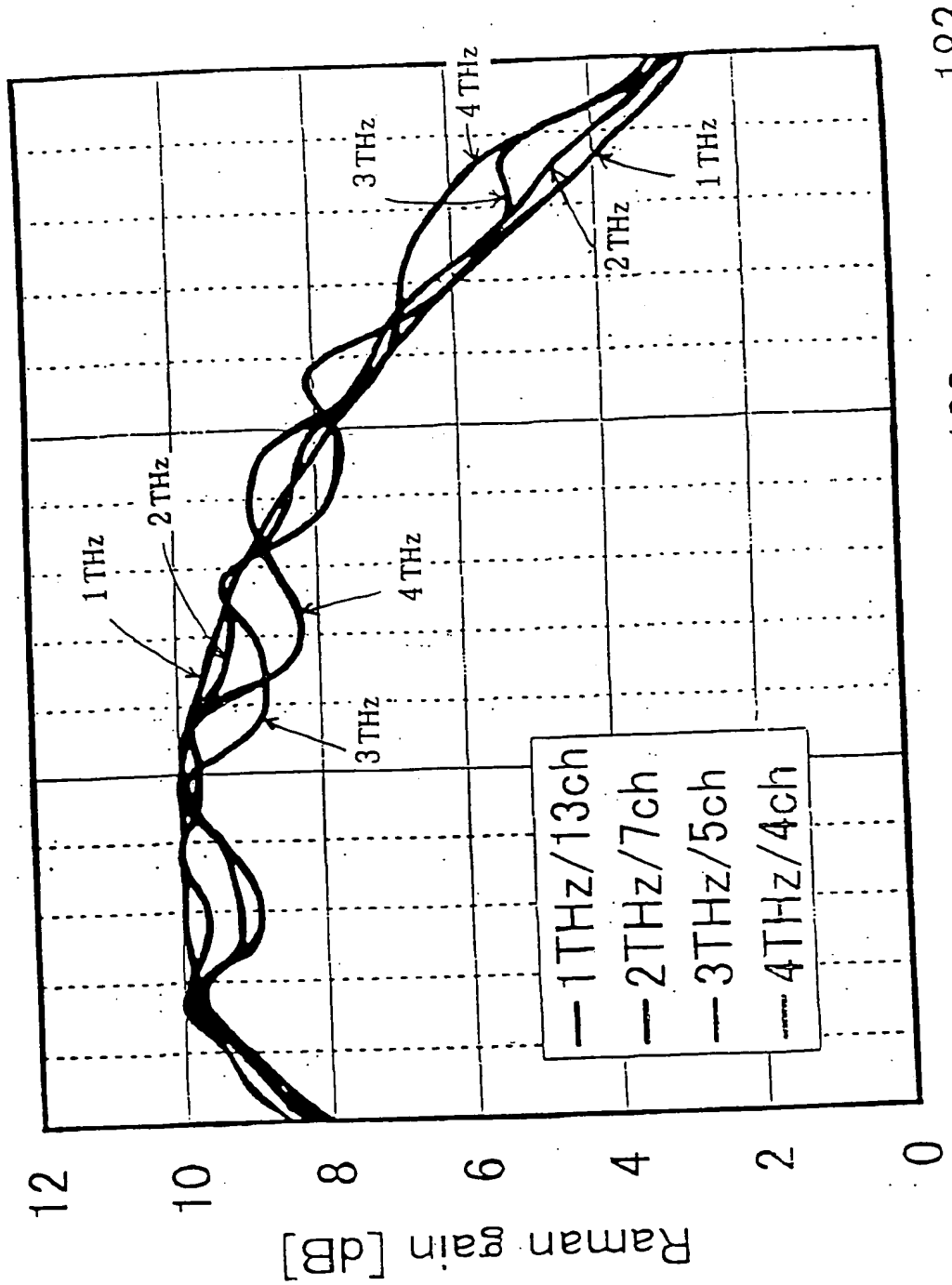

Raman gain [dB]
12
10
8
6
4
2
0
183
188
193
198
Frequency [THz]
1THz/13ch
2THz/7ch
3THz/5ch
4THz/4ch
1 THz
2 THz
3 THz
4 THz
1 THz
2 THz
3 THz
4 THz

FIG. 57

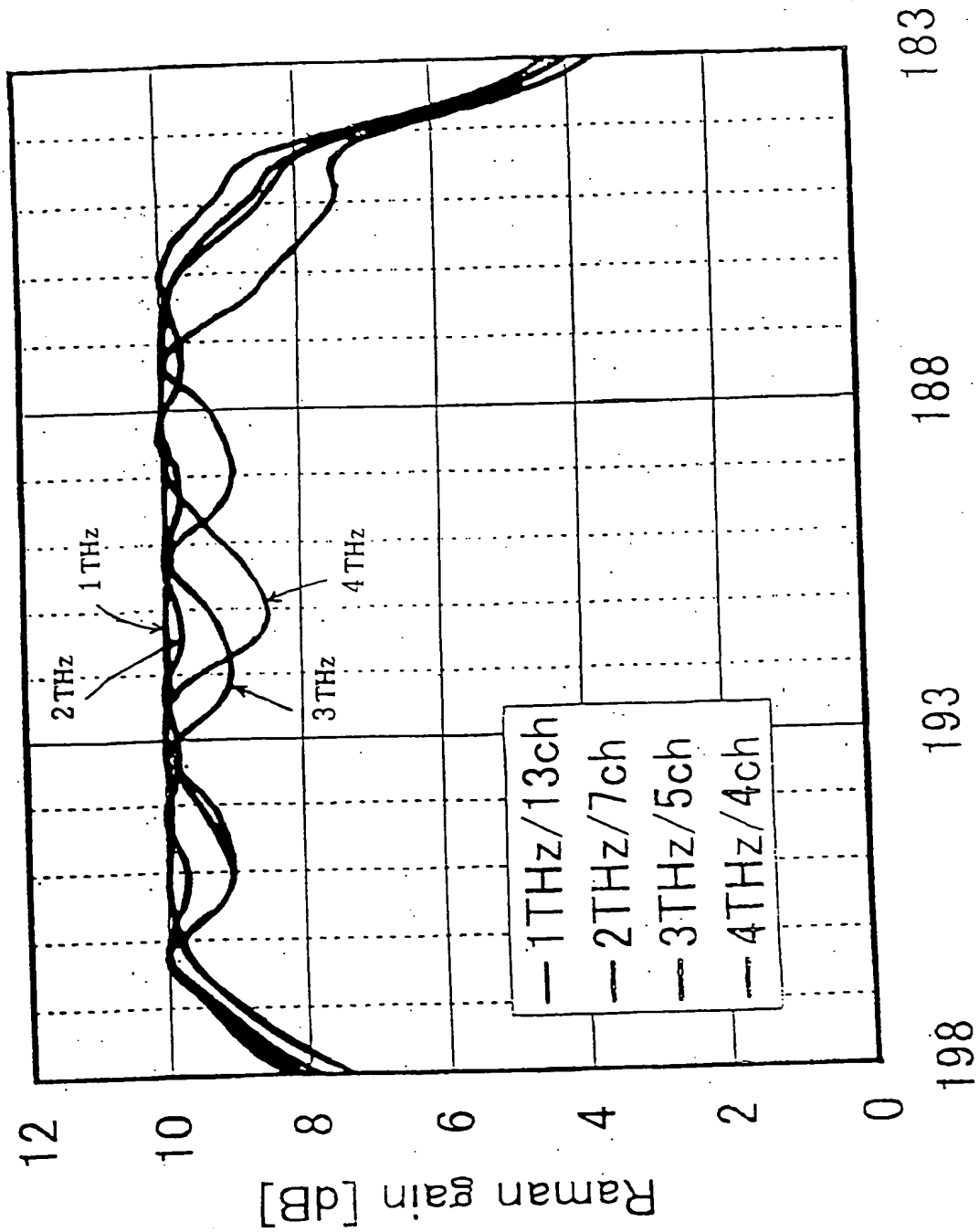

Raman gain [dB]
12
10
8
6
4
2
0
198
193
188
183
Frequency [THz]
1THz/13ch
2THz/7ch
3THz/5ch
4THz/4ch
1 THz
2THz
3 THz
4 THz

FIG. 58

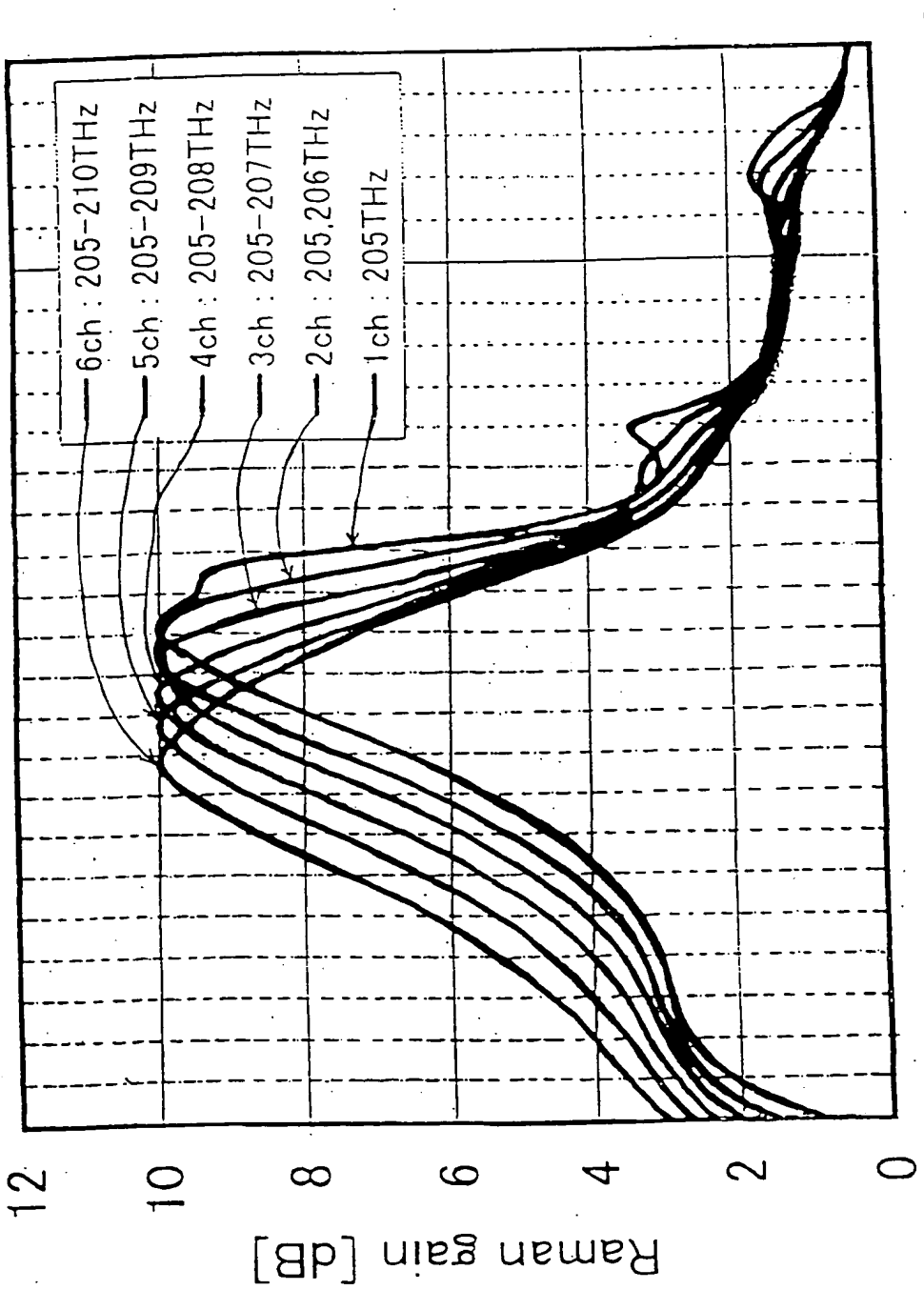

6ch : 205-210THz
5ch : 205-209THz
4ch : 205-208THz
3ch : 205-207THz
2ch : 205.206THz
1ch : 205THz
Raman gain [dB]
12
10
8
6
4
2
0
203
198
193
188
183
178
Frequency [THz]

FIG. 59

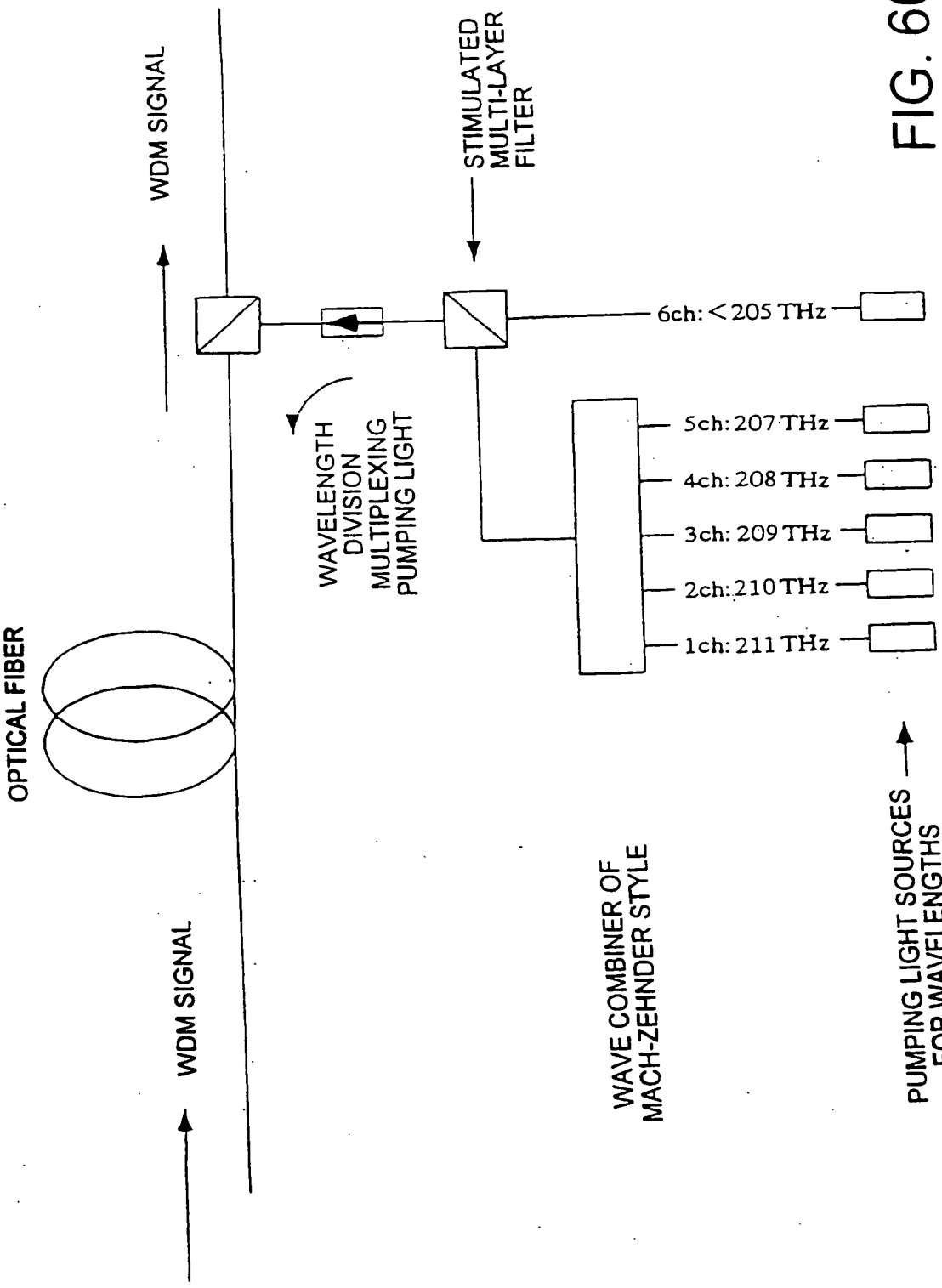

WDM SIGNAL
STIMULATED MULTI-LAYER FILTER
6ch: < 205 THz
5ch: 207 THz
4ch: 208 THz
3ch: 209 THz
2ch: 210 THz
1ch: 211 THz
WAVELENGTH DIVISION MULTIPLEXING PUMPING LIGHT
OPTICAL FIBER
WDM SIGNAL
WAVE COMBINER OF MACH-ZEHNDER STYLE
PUMPING LIGHT SOURCES FOR WAVELENGTHS

FIG. 60

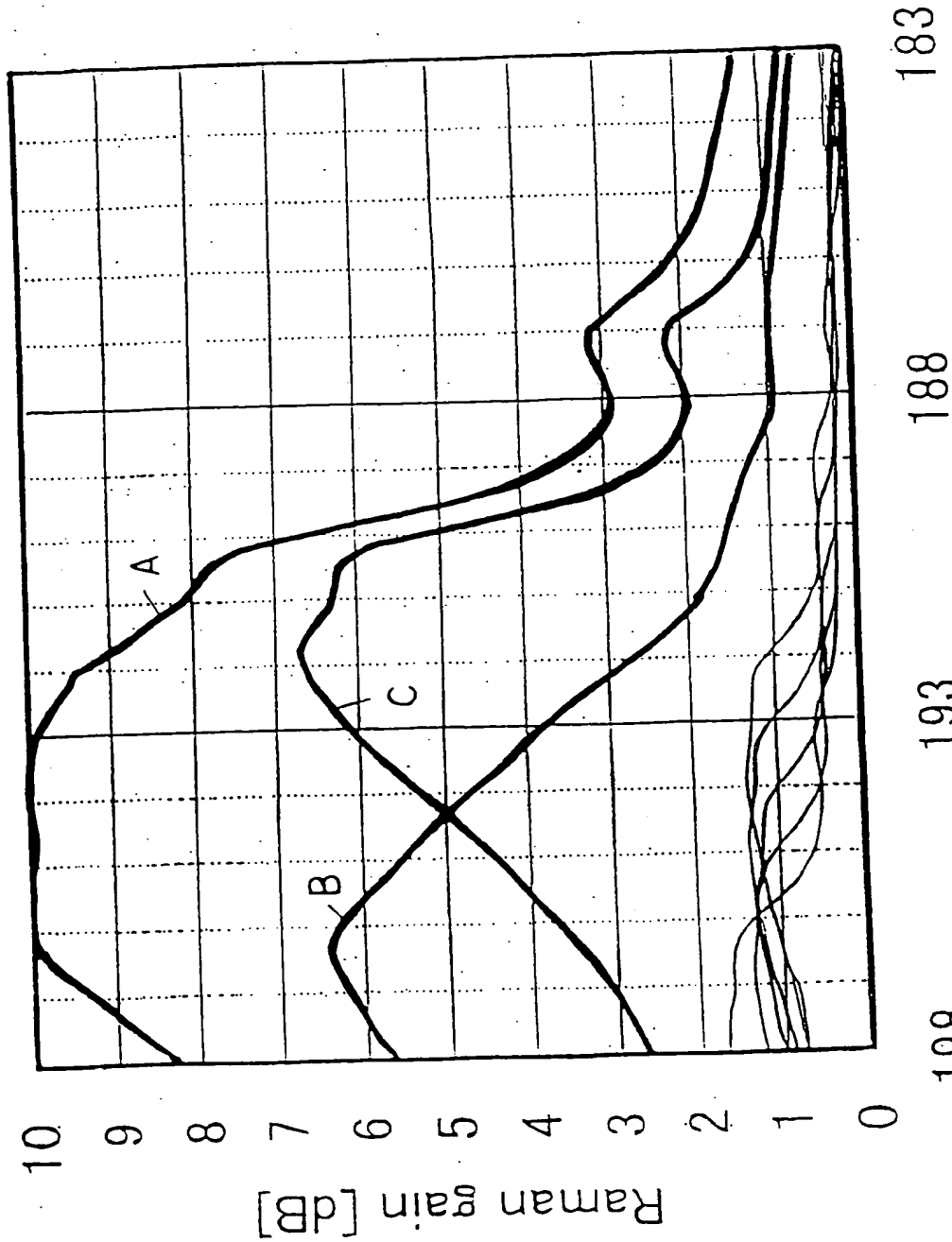

Raman gain [dB]
10
9
8
7
6
5
4
3
2
1
0
A
B
C
183
188
193
198
Frequency [THz]

FIG. 61

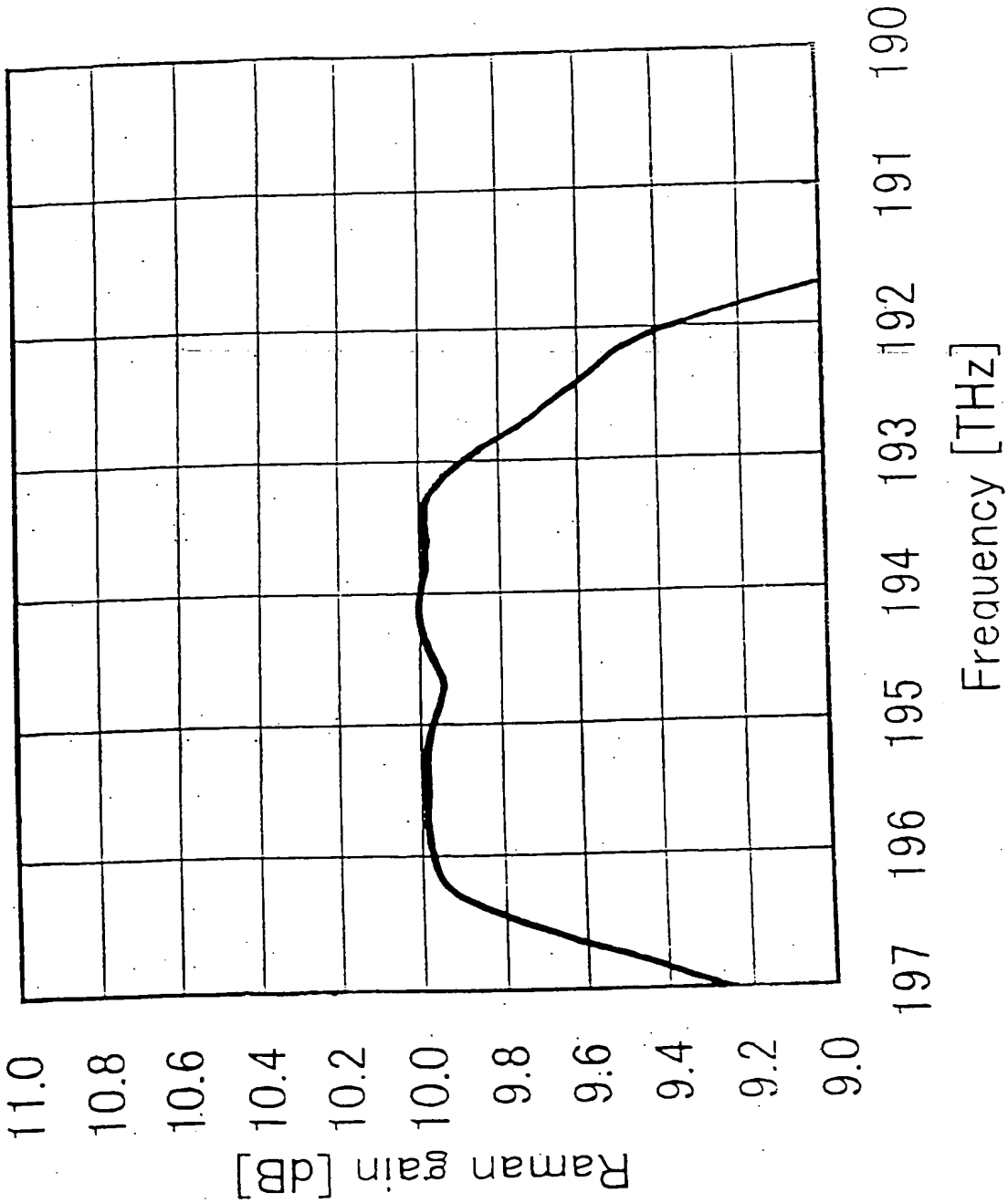

Raman gain [dB]
11.0
10.8
10.6
10.4
10.2
10.0
9.8
9.6
9.4
9.2
9.0
Frequency [THz]
197
196
195
194
193
192
191
190

FIG. 62

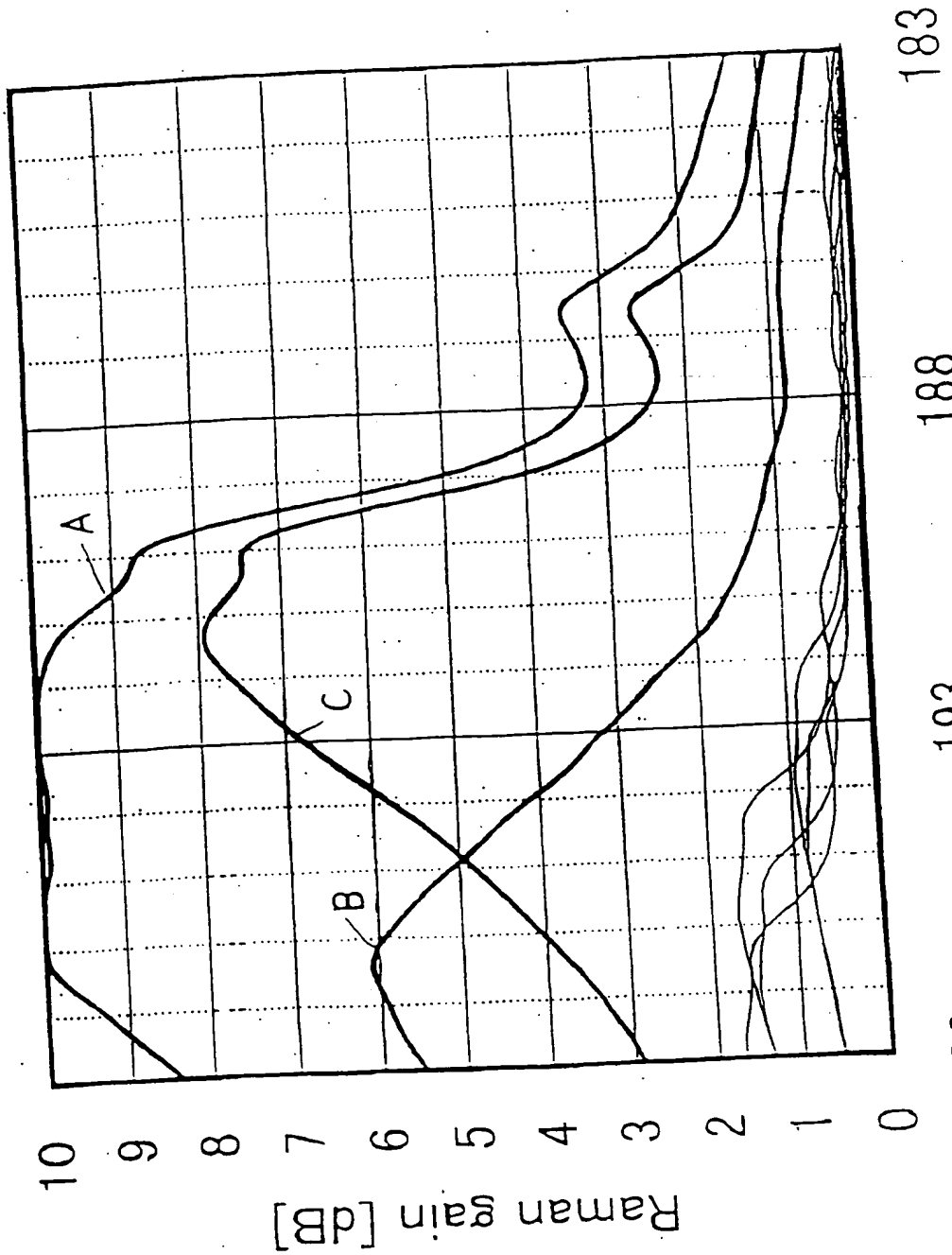
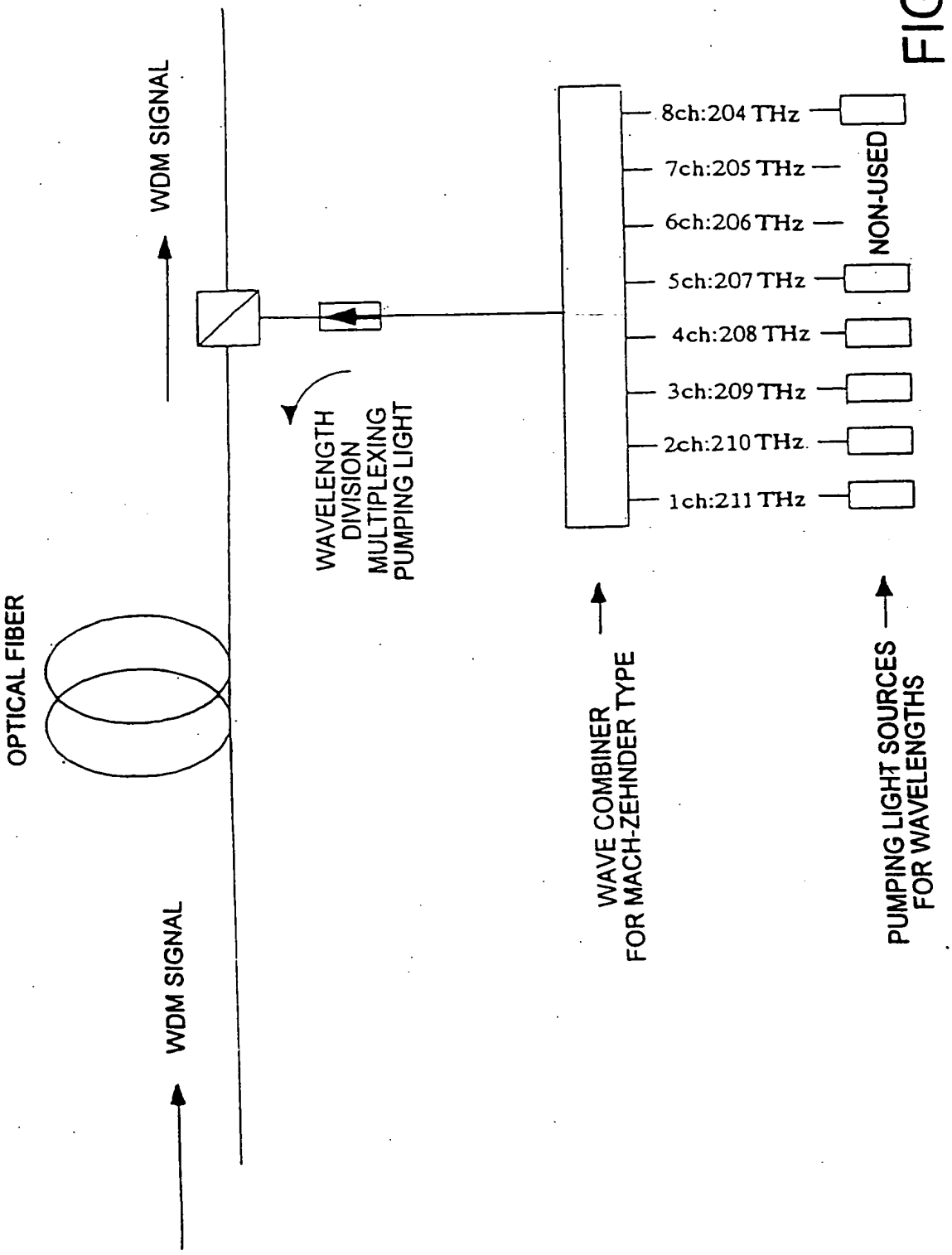

Raman gain [dB]
10
9
8
7
6
5
4
3
2
1
0
A
B
C
183
188
193
198
Frequency [THz]

FIG. 63


Raman gain [dB]
11.0
10.8
10.6
10.4
10.2
10.0
9.8
9.6
9.4
9.2
9.0
Frequency [THz]
190
191
192
193
194
195
196
197

FIG. 64

FIG. 65


WDM SIGNAL
WAVELENGTH DIVISION MULTIPLEXING PUMPING LIGHT
8ch:204 THz
7ch:205 THz
6ch:206 THz
5ch:207 THz
4ch:208 THz
3ch:209 THz
2ch:210 THz
1ch:211 THz
NON-USED
OPTICAL FIBER
WDM SIGNAL
WAVE COMBINER FOR MACH-ZEHNDER TYPE
PUMPING LIGHT SOURCES FOR WAVELENGTHS

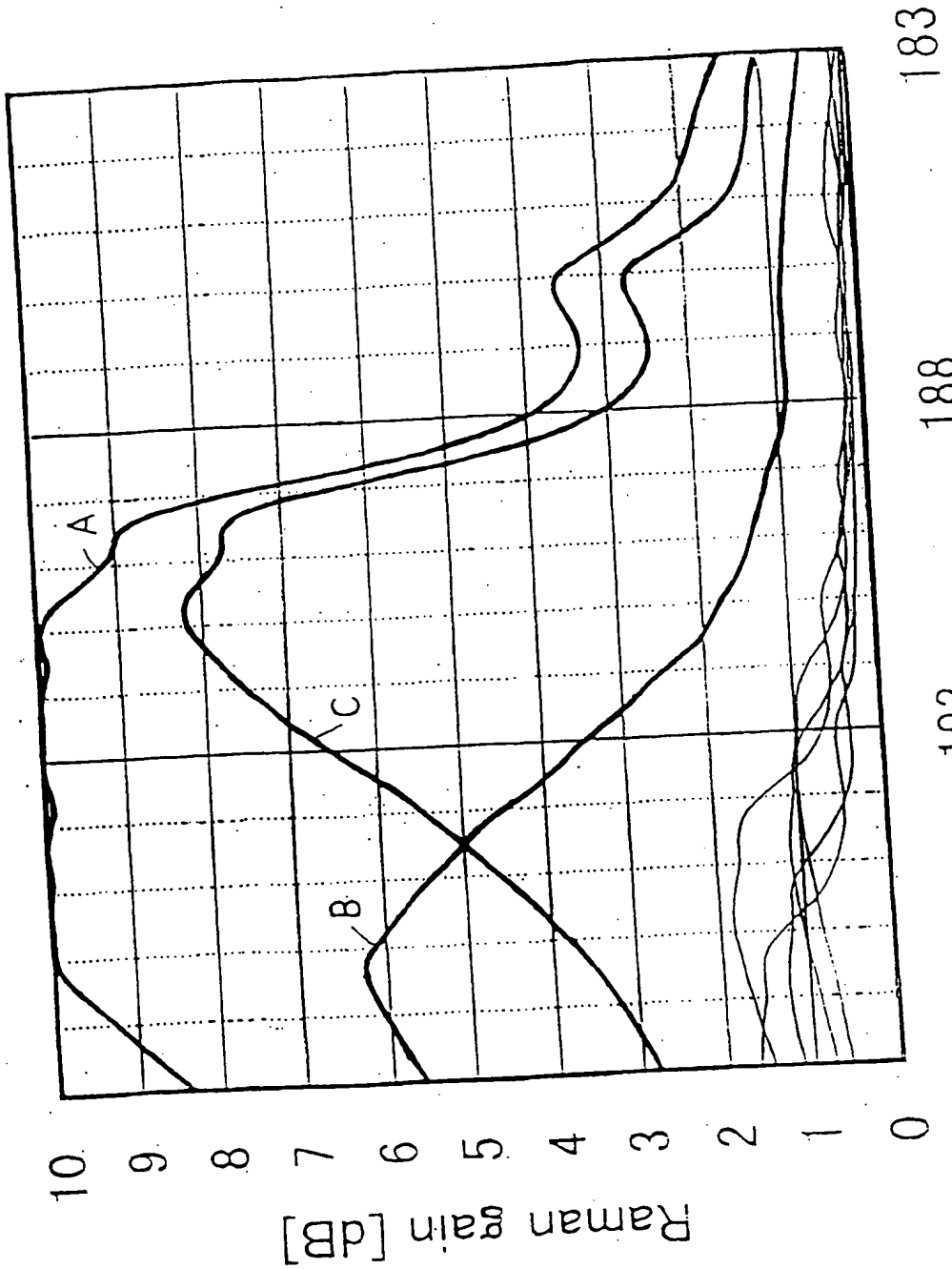

Raman gain [dB]
10
9
8
7
6
5
4
3
2
1
0
Frequency [THz]
183
188
193
198
A
B
C

FIG. 66

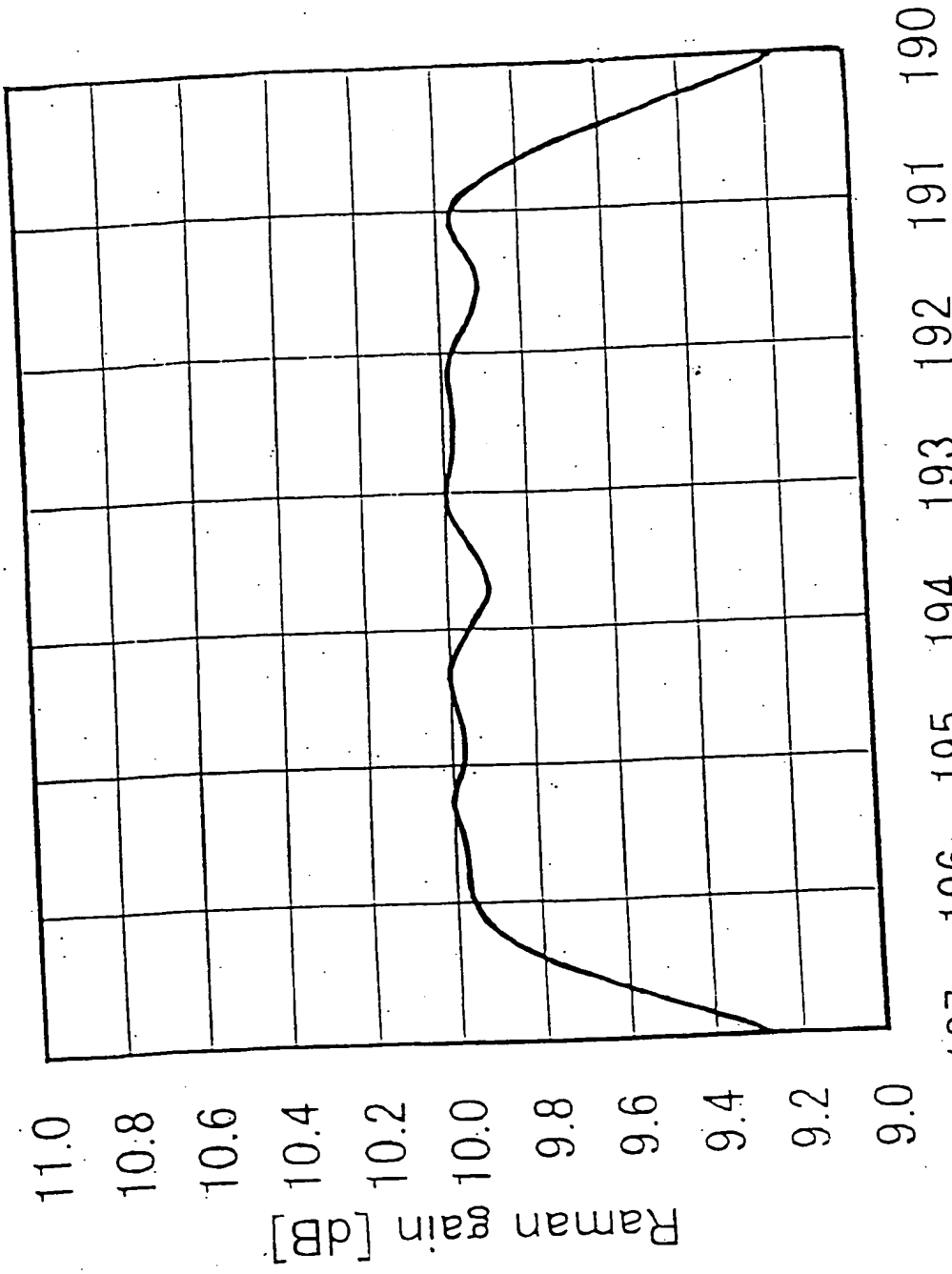
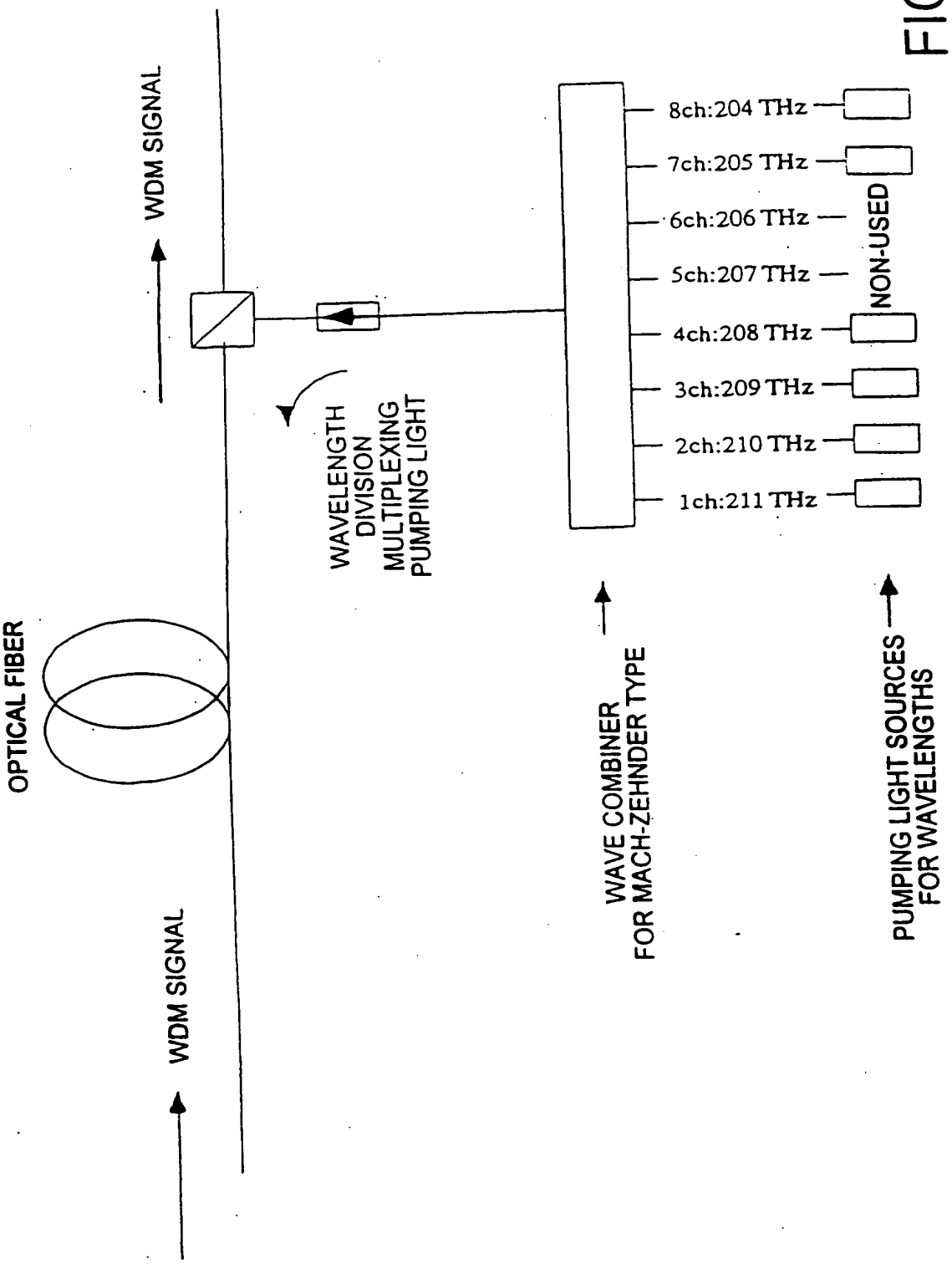

Raman gain [dB]
11.0
10.8
10.6
10.4
10.2
10.0
9.8
9.6
9.4
9.2
9.0
Frequency [THz]
190
191
192
193
194
195
196
197

FIG. 67

FIG. 68


WDM SIGNAL
WAVELENGTH DIVISION MULTIPLEXING PUMPING LIGHT
8ch:204 THz
7ch:205 THz
6ch:206 THz
5ch:207 THz
4ch:208 THz
3ch:209 THz
2ch:210 THz
1ch:211 THz
NON-USED
OPTICAL FIBER
WDM SIGNAL
WAVE COMBINER FOR MACH-ZEHNDER TYPE
PUMPING LIGHT SOURCES FOR WAVELENGTHS

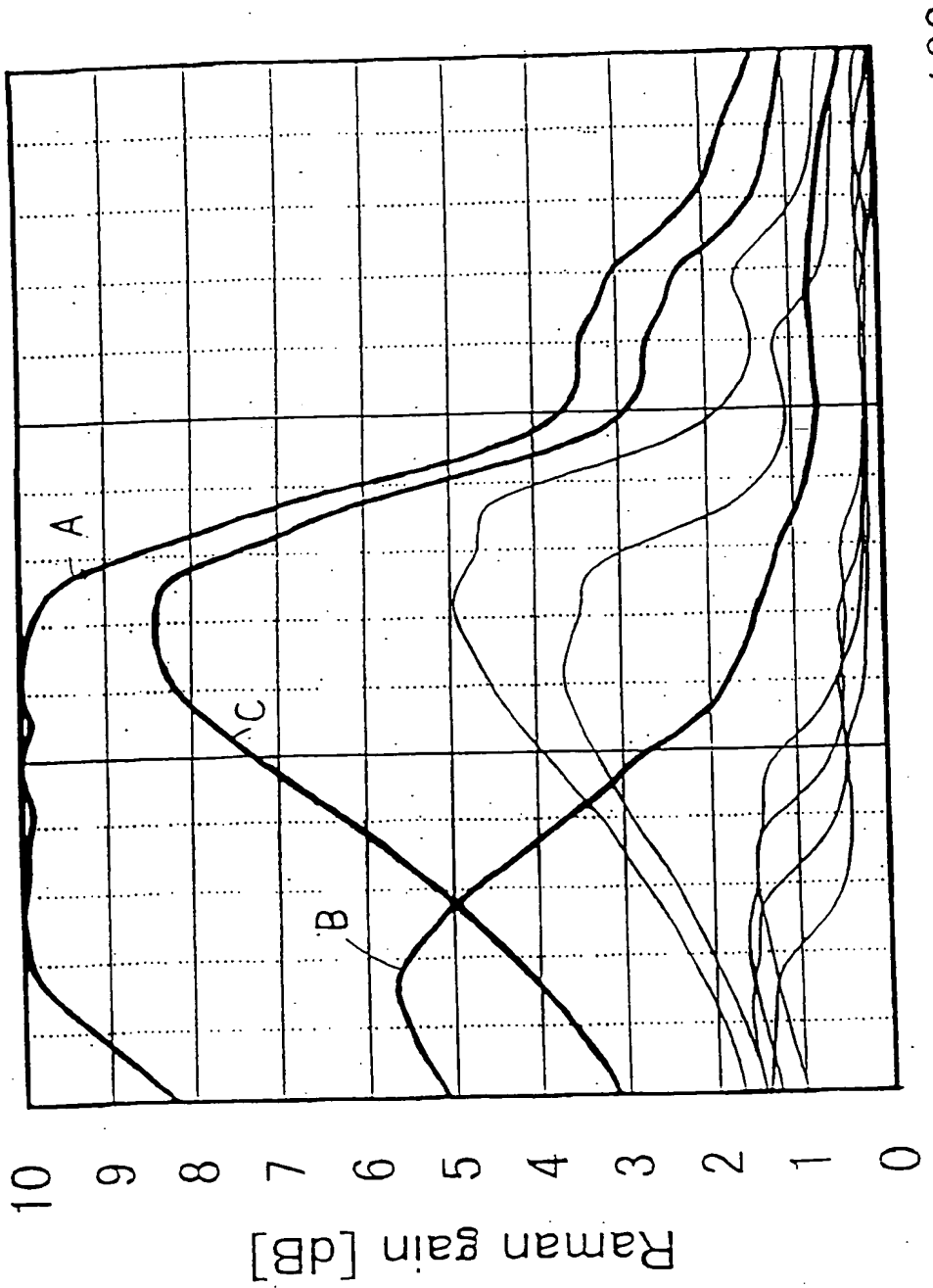

Raman gain [dB]
10
9
8
7
6
5
4
3
2
1
0
Frequency [THz]
183
188
193
198
A
B
C

FIG. 69

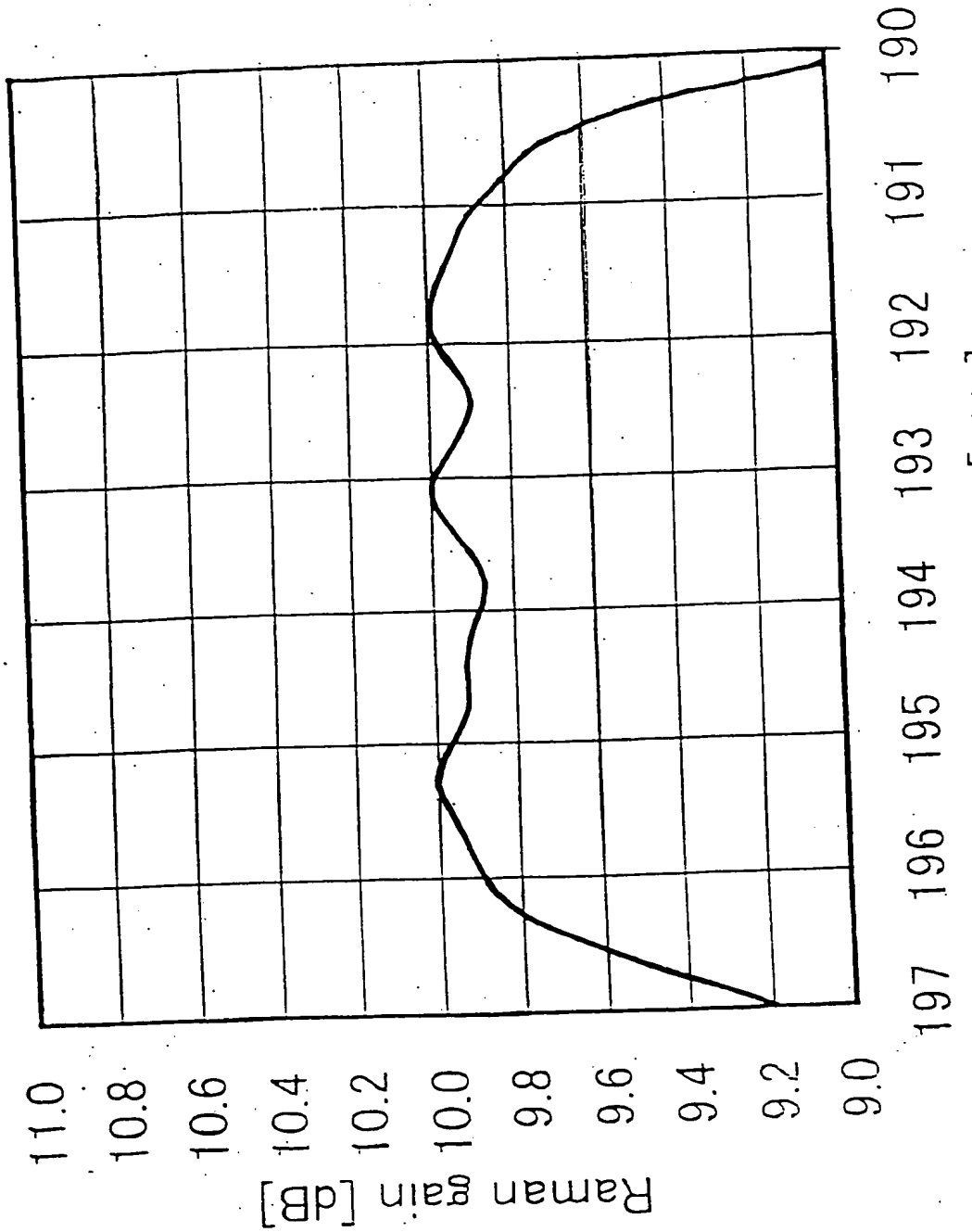

Raman gain [dB]
11.0
10.8
10.6
10.4
10.2
10.0
9.8
9.6
9.4
9.2
9.0
Frequency [THz]
190
191
192
193
194
195
196
197

FIG. 70

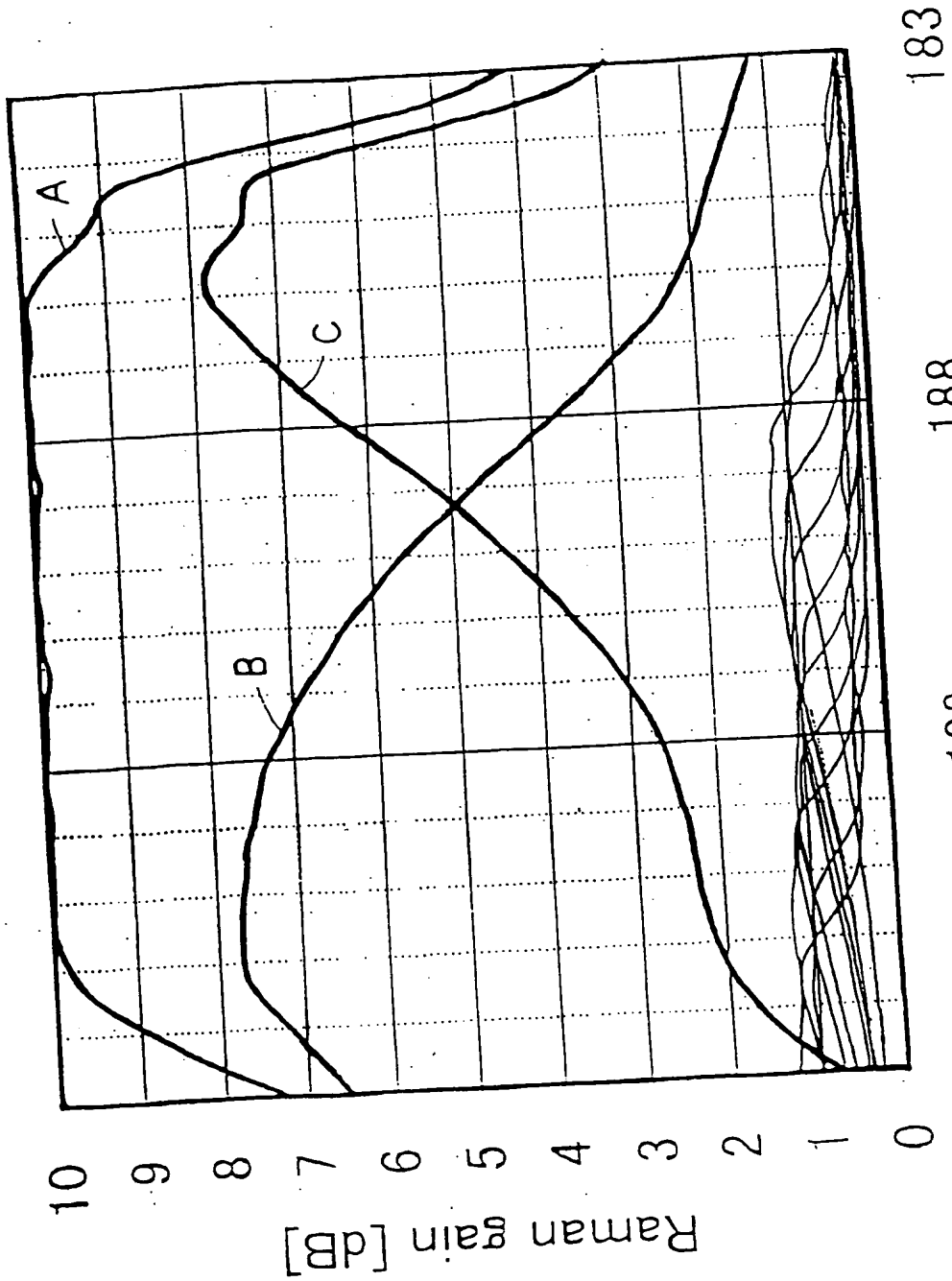

A
B
C
Raman gain [dB]
10
9
8
7
6
5
4
3
2
1
0
Frequency [THz]
183
188
193
198

FIG. 71

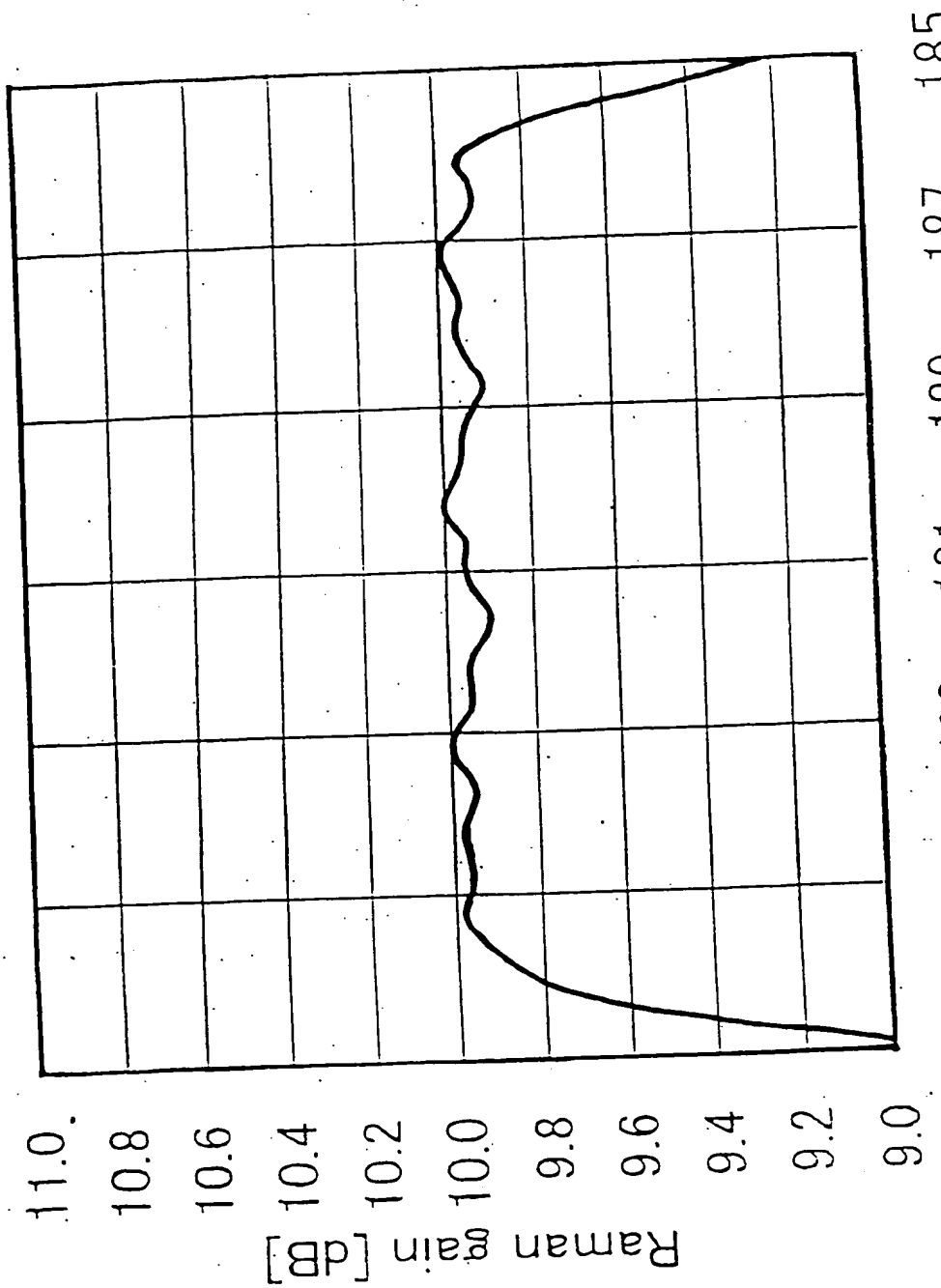

Raman gain [dB]
11.0
10.8
10.6
10.4
10.2
10.0
9.8
9.6
9.4
9.2
9.0
Frequency [THz]
185
187
189
191
193
195
197

FIG. 72

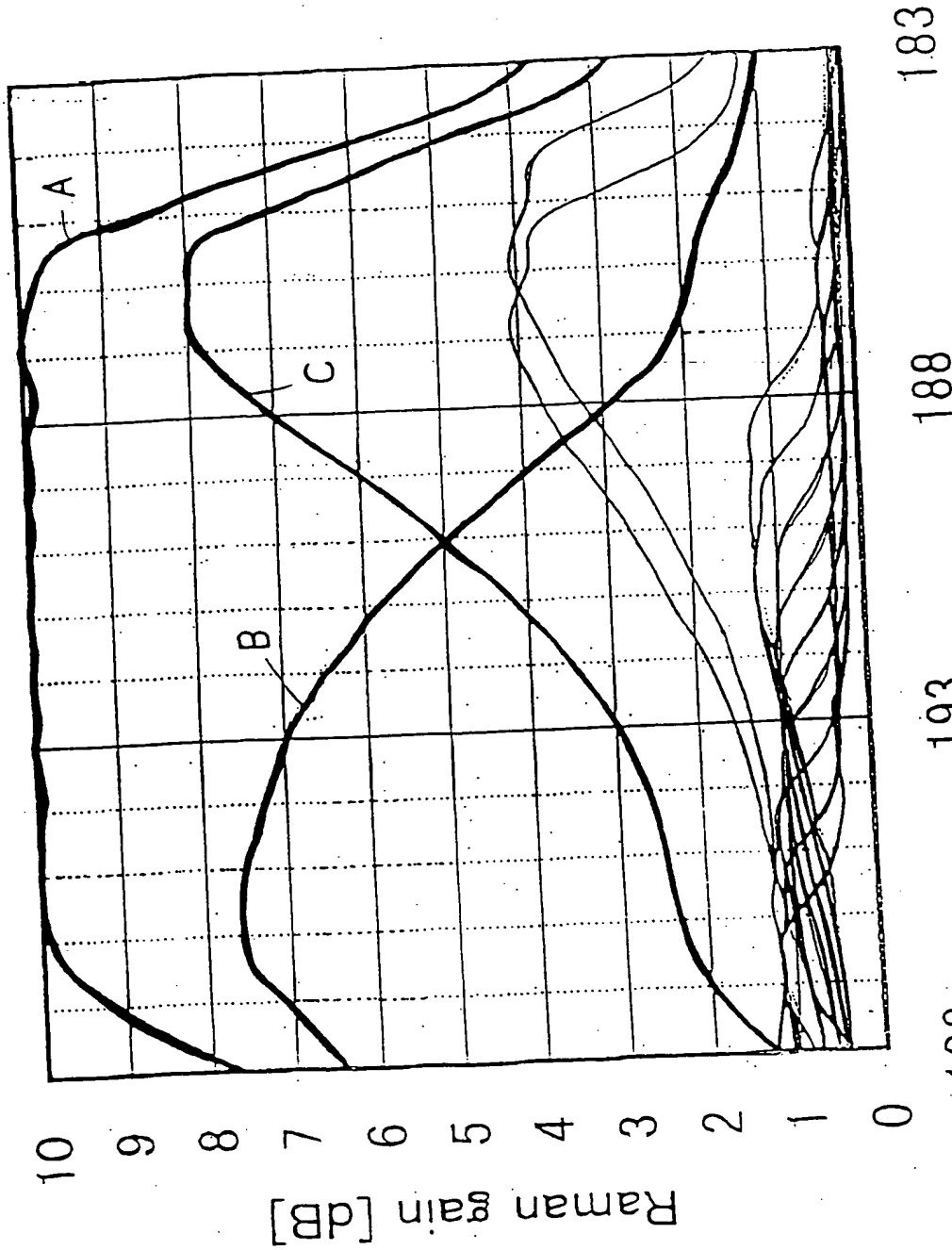

A
B
C
Raman gain [dB]
10
9
8
7
6
5
4
3
2
1
0
183
188
193
198
Frequency [THz]

FIG. 73

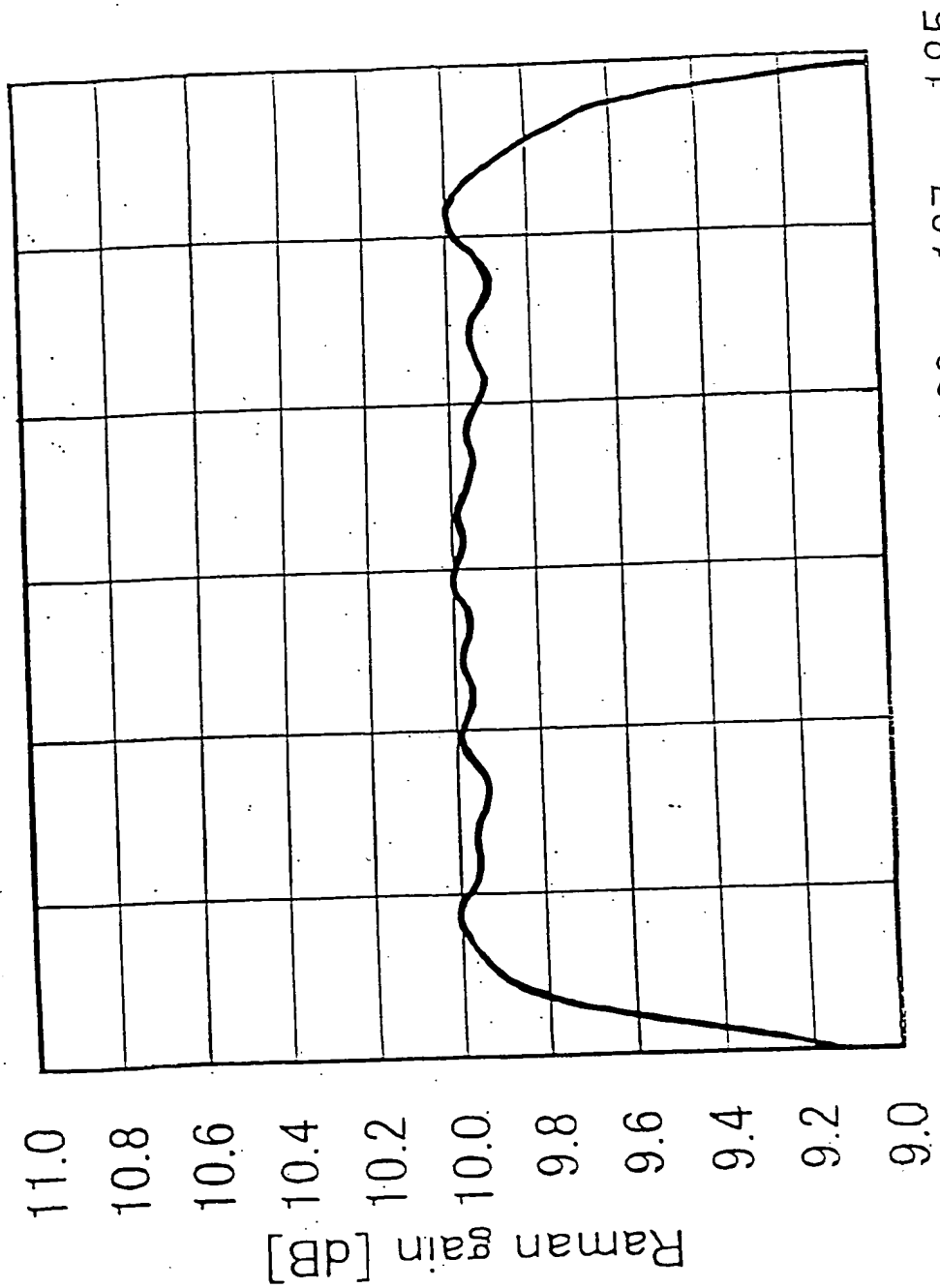

Raman gain [dB]
11.0
10.8
10.6
10.4
10.2
10.0
9.8
9.6
9.4
9.2
9.0
Frequency [THz]
185
187
189
191
193
195
197

FIG. 74